August 1895.] [No. 59.

PROCEEDINGS
OF THE
PHYSICAL SOCIETY
OF LONDON.

VOL. 13. PART 9.

OFFICERS AND COUNCIL.

President.
Capt. W. de W. Abney, R.E., C.B., D.C.L., F.R.S.

Vice-Presidents who have filled the Office of President.
Dr. J. H. Gladstone, F.R.S.
Prof. G. C. Foster, F.R.S.
Prof. W. G. Adams, M.A., F.R.S.
Lord Kelvin, D.C.L., LL.D., P.R.S.
Prof. R. B. Clifton, M.A., F.R.S.
Prof. A. W. Reinold, M.A., F.R.S.
Prof. W. E. Ayrton, F.R.S.
Prof. G. F. Fitzgerald, M.A., F.R.S.
Prof. A. W. Rücker, M.A., F.R.S.

Vice-Presidents.
Walter Baily, M.A.
Maj.-Gen. E. R. Festing, R.E., F.R.S.
Prof. J. Perry, D.Sc., F.R.S.
G. Johnstone Stoney, M.A., F.R.S.

Secretaries.
T. H. Blakesley, M.A., M.I.C.E. | H. M. Elder, M.A.

Treasurer.
Dr. E. Atkinson.

Demonstrator and Librarian.
C. Vernon Boys, F.R.S.

Other Members of the Council.
Shelford Bidwell, M.A., LL.B., F.R.S.
Prof. W. Crookes, F.R.S.
L. Fletcher, M.A., F.R.S.
R. T. Glazebrook, M.A., F.R.S.
G. Griffith, M.A.
Prof. O. Henrici, Ph.D., F.R.S.
Prof. G. M. Minchin, M.A.
James Swinburne.
Prof. S. P. Thompson, D.Sc., F.R.S.
Prof. S. Young, D.Sc., F.R.S.

Editor.
J. Swinburne.
66 *Victoria Street*, S.W.

Abstractors.
R. Appleyard.
E. H. Barton, D.Sc.
R. E. Baynes, M.A.
H. Borns, Ph.D.
G. H. Bryan, M.A., F.R.S.
S. H. Burbury, M.A.
C. V. Burton, D.Sc.
J. W. Capstick, M.A., D.Sc.
A. Daniell, M.A.
T. E. Ewan.
E. E. Fournier d'Albe.
Prof. A. Gray, M.A.
A. Griffiths, B.Sc.
J. L. Howard, D.Sc.
Prof. D. E. Jones, B.Sc.
R. A. Lehfeldt, B.A., B.Sc.
T. Preston, M.A.
W. G. Rhodes, M.Sc.
S. Rideal, D.Sc., F.I.C.
E. C. Rimington.
J. W. Rodger.
G. F. C. Searle, M.A.
S. Skinner, M.A.
W. E. Sumpner, D.Sc.
F. T. Trouton, D.Sc.
W. Watson, B.Sc.
W. C. D. Whetham, M.A.
L. R. Wilberforce, M.A.

Reporter.
W. Watson, B.Sc.

LONDON:
TAYLOR AND FRANCIS, RED LION COURT, FLEET STREET.

Price to Non-Members, ~~Two Shillings & Sixpence.~~

Page

XXXVIII. Tests of Glow-Lamps, and Description of the Measuring Instruments Employed. By Prof. W. E. AYRTON, F.R.S., and E. A. MEDLEY (*continued*) 469

XXXIX. The Tin-Chromic Chloride Cell. By S. SKINNER, M.A. 477

XL. Note on a Simple Graphic Illustration of the Determinantal Relation of Dynamics. By G. H. BRYAN 481

XLI. On the Mechanical Analogue of Thermal Equilibrium between Bodies in Contact. By G. H. BRYAN and LUDWIG BOLTZMANN. (Abstract.) 485

XLII. Note on a Neglected Experiment of Ampère. By SILVANUS P. THOMPSON 493

XLIII. A Theory of the Synchronous Motor. By W. G. RHODES, M.Sc. 502

NAME INDEX (ABSTRACTS).

Aschkinass, 355.
Ascoli, 352.
Antusch, 362.
Bandrowski, 346.
Berthelot, 361, 362.
Bjerknes, 355.
Bodländer, 362.
Le Boisbaudran, 361.
Bordier, 353.
Borel, 341.
Boussinesq, 350.
Bouty, 350.
Branly, 356.
Broca, 342.
Brown-Séquard, 343.
Bruner, 347, 362.
Brunhes, 342.
Cantone, 331, 334.
Chauveau, 347.
Cornu, 343.
Cotton, 343.
Crookes, 340, 345.
Curie, 357.
Delebecque, 334.
Deslandres, 340, 344.
Eisler, 358.
Faidiga, 337.
Fizeau, 344.
Fomm, 351.
Fouqué, 334.
Foussereau, 345.
Franklin, 354.
Garbasso, 355.
Gouy, 345, 351.
Graetz, 351.
Grützmacher, 348.
Hale, 346.
Hautefeuille, 332.
Helmholtz, 355.
Henry, 343.
Higgins, 346.
van't Hoff, 333.
Hoitsema, 332.
Holden, 354.
Hollemann, 362.
Houdin, 343.
Houston, 360.
Janssen, 332, 341.
Kayser, 346.
Kennelly, 360.
Kilian, 334.
Koch, 336, 340.
Lagrange, 356.
Lecercle, 359.
Leduc, 339.
Lockyer, 341, 345.
Lœwy, 335.
Mack, 352.
Maneuvrier, 348.
Moissan, 344.
Morley, 337.
Nodon, 356.
Oddone, 332.
Paschen, 345.
Paulin, 334.
Peddie, 331.
Planck, 357.
Plessner, 358.
Poincaré, 344.
Pollak, 353.
Priwoznik, 348.
Puiseux, 335.
Ramsay, 340, 341.
Raps, 359.
Rebeur-Paschwitz, 334.
Retgers, 333.
Righi, 352, 352.
Rinne, 333.
Rose, 346.
Le Royer, 334.
Runge, 345, 346.
Schrader, 336.
Spring, 347.
Sturm, 342.
Tammann, 361.
Troost, 332.
Vautier, 350.
Violle, 341, 350.
Weinek, 335.
Wiedemann, 358.
Zenger, 333.
Zepernick, 361.

at any time during the test, time being measured horizontally, and the values of the ordinates have been calculated from the following formula:—

Total cost per candle per 100 hours at the end of any number of hours t equals

$$100 \times \frac{\text{Board of Trade units used during time } t \times \text{Price of one Board of Trade unit}}{\text{Total Candle-hours during time } t}$$

$$+ 100 \times \frac{\text{Number of lamps used during time } t \times \text{Price of one lamp}}{\text{Total Candle-hours during time } t}.$$

The price of a kilowatt-hour we took as 4½*d* in fig. 12, and as 9*d*. in fig. 13, the cost of a new lamp being taken as 1*s*. 9*d*. in both sets of curves.

Of course, it will be seen from the formula quoted above, that whenever a lamp breaks and a new one is put in its place, there must be a sudden, though temporary, rise in the cost per candle-hour due to the cost of the new lamp; but this rise becomes less marked as the number of lamps included in the calculations increases, and would have become inappreciable if the tests could have been carried on for a sufficient length of time.

The first three lamps to break in both the 102 and the 104 volt groups were replaced by the lamps which we had previously run at 102 and 104 volts respectively for 110 hours; and in calculating the cost-curves we have added in the watt-hours and the candle-hours due to these previous runs; we have also added to the abscissæ of the curves the 110 hours.

On examining the total-cost curves on figs. 12 and 13, it is at once apparent that they nowhere show any such rise in the cost of producing light, as was seen in the similar curves for American lamps (fig. 5). The curves in fig. 12, for which the price of a Board-of-Trade unit was taken as 4½*d*., do *not* turn up *at any* point, not even for the three lamps run at 101 volts, which lasted unbroken for over 1300 hours.

In fig. 13, however, for drawing the curves on which the price of a Board-of-Trade unit has been taken at 9*d*., there are slight indications of the curves turning up: for example, the curve for the 100-volt group rises a little at 850 hours, at which time the lives of the three lamps being tested were 850, 850, and 278 hours; and, again, at about 1600 hours, when the lives of the three living lamps were 1028, 643, and 433 hours, the cost per candle-hour rises a little. In the group run at 101 volts the cost of lighting began to rise a little after the lamps had been lit for 1100 hours; and in the 102-volt group the curve (fig. 13) turns up a little at 1700 hours, at which time the ages of the lamps alight were 928, 678, and 552 hours. But at no one of these points is there a sufficient rise to indicate that a time has been reached when it would be good economy to discard lamps.

The remaining total cost curve on fig. 13, viz. that for the group of lamps run at 104 volts, when the price of the Board of Trade unit is taken at 9*d*., does not show any indication of a minimum point.

Hence, generally, we may conclude that when the modern Edison-Swan 8 C.P. 100-volt lamps such as we have been testing, costing 1*s*. 9*d*. per lamp, are supplied with energy costing 9*d*. per Board of Trade unit, no economy will be gained by discarding the lamps before the filaments break.

This important result is of course due to the fact, already pointed out, that there is no marked decrease in the candle-power of the lamps during their lives.

Owing to the extent to which the individual lamps varied among themselves, it is difficult to say which of the four pressures at which we tested lamps would be the most economical to use. The three lamps tested at 101 volts seem to have been quite abnormal, their efficiency being very low, and, as a consequence, their lives very long.

With a Board of Trade unit costing 4½*d*., the lamps tested at 100 volts gave the cheapest light, and as they do not seem to have been above the average in quality this result may probably be safely taken as correct.

With energy costing 9*d*. per Board of Trade unit (fig. 13) there does not seem much to choose between the total cost of producing light with the three pressures of 100, 102, and 104 volts, excepting that the use of 104 volts would introduce an extra expense arising from the labour of frequently replacing broken lamps.

The two conclusions, then, to which we are led by a study of these total-cost curves on figs. 12 and 13 are :—

1. The modern Edison-Swan 8 C.P. 100-volt lamps such as we tested should not be discarded until the filaments break.
2. No marked economy can be gained by over-running this type of lamp.

Addition made January 25, 1895.

The question arises—what is the cause of the marked rise in candle-power which occurred with all the lamps tested by us during 1893 and 1894? In the early summer of 1894, when our tests were approaching completion, Mr. Howell, in contributing to a discussion at the American Institute of Electrical Engineers, stated that such a rise in candle-power was due to the vacuum of the lamp improving during the early part of its life. Therefore, after we had stopped the main investigation, we made some experiments to test the validity of Mr. Howell's explanation.

We applied the induction-coil vacuum-test to some dozen Edison-Swan lamps when quite new, and again after they had been run for about 80 hours at their normal pressure of 100 volts. In *every case* we found that the vacuum had apparently improved; for using a spark of about 8 millimetres in length, the lamps when *new* were entirely filled with a bright blue glow accompanied with some bright white patches on the glass; whereas, after a run of about 80 hours at a pressure of 100 volts, this phosphorescent effect with the 8 millimetre spark was either entirely absent, or consisted of only a faint nebulous glow which did *not* fill the lamp-bulb, and there was very little light on the surface of the glass.

Thus it appeared as if Mr. Howell's explanation of the great increase in the light given out by a glow-lamp during the early portion of its life was correct.

But this conclusion which we arrived at last year has been modified by tests that we have been carrying out on Edison-Swan glow-lamps purchased since our paper was sent in to the Physical Society in November 1894. For we find that,—while the induction-coil vacuum-test applied to these lamps when they are new, and after a run of 80 hours at the normal pressure of 100 volts, shows that the vacuum apparently improves,—this improvement in the vacuum is not accompanied with the great rise in candle-power which we found with all the Edison-Swan lamps purchased in 1892 and 1893, the tests of which form the subject of this paper. And yet the lamps are all marked in the same way, "100 E.F. 8," and they all look alike.

In the case of a set of these Edison-Swan lamps, purchased on January 21, 1895, not merely were the current and the light periodically measured, but the induction-coil vacuum-test was applied at intervals during the 80 hours' run; and it was found that the change in the phosphorescent appearance of the lamp, and the consequent apparent increase in the vacuum, was produced slowly and not suddenly on the first application of the pressure of 100 volts.

The following are the results of the tests of this batch of six lamps. The light was measured with a Harcourt-Pentane Standard, the potential difference with the Ayrton and Mather reflecting electrostatic voltmeter, and the current with the strip of manganin shunted with the Ayrton and Mather moving coil-galvanometer; this voltmeter and the ammeter combination being the same as those employed with all the lamps tested previously. But both instruments were carefully calibrated on January of this year, to make quite certain that the different behaviour of these newer lamps was not merely an apparent one produced by some change having occurred in the sensibilities of the measuring-instruments.

The insulation of the lamp-holders was carefully cleaned and the contact-surfaces scraped before these tests were made.

From these tests it is seen that, in the case of lamps Nos. XI. and XIV., there was practically no change either in the light or in the power absorbed during the first 80 hours of the running at the constant pressure of 100 volts; and that in the case of the remainder of this batch of lamps the increase in the light and in the power absorbed was comparatively small, the greatest change being with lamp No. XII., where the light rose by about 11 per cent. and the power by about 4 per cent. This is a very different result from that obtained with the Edison-Swan lamps previously tested, and run at a constant pressure of 100 volts, for there the total

Six Edison-Swan Lamps, marked "100 E.F. 8," purchased January 21, 1895, marked by us IX., X., XI., XII., XIII., XIV., and run at 100 Volts.

Filaments placed at an angle of 45° with the Photometer-Bench.

Hours of Running.	Power, in Watts.	Candle-Power.	Watts per Candle.
Lamp No. IX.			
0	41·3	9·70	4·26
1 hour 40 minutes.	41·3	9·70	4·26
6 hours 10 minutes.	41·5	9·70	4·28
13 hours 30 minutes.	41·6	9·67	4·30
42 hours 30 minutes.	41·9	9·85	4·25
80 hours	42·5	9·85	4·31
Lamp No. X.			
0	40·35	7·85	5·14
1 hour 45 minutes.	40·4	7·95	5·08
6 hours 15 minutes.	40·5	7·92	5·11
13 hours 35 minutes.	40·6	7·92	5·12
42 hours 35 minutes.	40·9	8·2	4·99
80 hours 5 minutes.	41·5	8·5	4·88
Lamp No. XI.			
0	39·8	7·89	5·05
1 hour 50 minutes.	39·8	8·00	4·97
6 hours 20 minutes.	39·8	8·11	4·91
13 hours 40 minutes.	39·8	7·95	5·01
42 hours 40 minutes.	39·8	8·00	4·97
80 hours 10 minutes.	40·1	8·00	5·01
Lamp No. XII.			
0	39·85	7·78	5·12
1 hour 55 minutes.	40·1	8·07	4·97
6 hours 25 minutes.	40·25	8·05	5·00
13 hours 45 minutes.	40·41	7·95	5·08
42 hours 45 minutes.	40·75	8·3	4·91
80 hours 15 minutes.	41·4	8·7	4·76
Lamp No. XIII.			
0	40·75	8·06	5·05
2 hours	40·6	8·06	5·04
6 hours 30 minutes.	40·5	8·17	4·95
13 hours 50 minutes.	40·5	7·85	5·15
42 hours 50 minutes.	40·5	7·9	5·13
80 hours 20 minutes.	40·6	8·4	4·67
Lamp No. XIV.			
0	41·2	8·49	4·85
2 hours 5 minutes.	41·2	8 65	4·76
6 hours 35 minutes.	41·2	8·65	4·76
13 hours 55 minutes.	41·2	8·49	4·85
42 hours 55 minutes.	41·2	8·6	4·80
80 hours 25 minutes.	41·5	8·5	4·89

light given out by the three lamps together rose by 35 per cent. in the first 100 hours of running, and the power by 7·55 per cent.

Since, then, as already stated, the vacuum, when tested periodically with the induction-coil, appeared to improve steadily with each of the six lamps Nos. IX. to XIV. during the run of 80 hours, it would appear that improvement in the vacuum was *not* the sole cause, as stated by Mr. Howell, for the great rise in the candle-power such as we observed with all the Edison-Swan lamps which we tested in 1893 and 1894.

It is possible that this rise in candle-power may have been due to a change in the surface of the filament causing the emissivity for heat to decrease, since that would raise the light emitted, as well as the number of candles per watt. Whether such a change in the heat-emissivity of the filament occurs with time we have not yet found out.

Another point of difference between this batch of six lamps Nos. IX. to XIV. and those which we tested during the main part of our investigation, is the relative inefficiency of these six lamps. For in no single test at any time during the 80 hours run with these six lamps were the watts per candle less than 4·25, and in many cases they were over 5; while with lamp No. XIII. the watts per candle, as seen in the last table, were as high as 5·15 after this lamp had been run for 13 hours 50 minutes. It is possible, then, that when in the body of the paper we spoke of the group of three lamps which we ran at a constant pressure of 101 volts as being "quite abnormal," because the average watts per candle required with this group during the run of 1340 hours were as high as 4·68, we ought rather to have spoken of the various other groups of lamps which we ran at the constant pressures of 100, 102, and 104 volts respectively as being abnormally good Edison-Swan lamps.

At any rate it is clear that it is at present impossible to state the most economical potential difference to employ with any Edison-Swan lamps marked "100 E.F. 8;" since batches of lamps so marked, and therefore nominally the same, really require very different potential differences to be employed to obtain maximum economy with a given price of lamp and of a kilowatt-hour.

It may, however, be concluded, from the curves shown in figs. 12 and 13, that the most economical potential difference to employ with any Edison-Swan lamps marked "100 E.F. 8," such as have been obtainable in the open market since 1892, is the potential difference that will cause the lamp during a large portion of its life to have an efficiency of about 0·25 candle per watt, corresponding with 4 watts per candle.

The value of this potential difference for any batch of these lamps may be determined approximately in the following way. From our tests, already referred to, of eleven Edison-Swan lamps, marked "100 E.F. 8," which had been used in a house for some 200 or 300 hours, we found that the relation between candle-power and pressure was given by

$$\text{Candle-power} = a \times (\text{volts})^{5\cdot91},$$

where a is a constant. Also we found that the relation between candle-power and watts for these lamps was given by

$$\text{Candle-power} = b \times (\text{watts})^{2\cdot9},$$

where b is a constant. Therefore

$$\text{Volts} = c \times (\text{watts per candle})^{-0\cdot258},$$

where c is a constant.

Hence if one has a batch of Edison-Swan lamps marked "100 E.F. 8," whose efficiency is, say, 0·222 candle per watt, corresponding with 4·5 watts per candle, when a pressure of 100 volts is applied to them, it would be probably most economical to run them at about 103 volts, since this is the pressure which the last equation tells us will be necessary to raise the efficiency of such lamps to 0·25 candle per watt.

From what precedes, it follows that, since the average efficiency of the 100 E.F. 8 Edison-Swan appears to be less than 0·25 candle per watt, the opinion expressed by one of us in an article entitled "New Lamps for Old," published in the 'Electrician' for September 29, 1893, was correct, viz. that it would be economical to overrun Edison-Swan lamps by applying a pressure about 3 per cent. higher than the marked pressure. And that the reason why this conclusion was apparently negatived by the results of the tests which we carried out during the winter of 1893 and a large portion of

1894, was because the various groups of lamps which we ran at the constant pressures of 100, 102, and 104 volts respectively consisted of specially good specimens.

In applying the rule that the economical potential difference is about the one which causes the lamp to produce 0·25 candle per watt, it is important, however, to examine 8-candle 100-volt Edison-Swan lamps when bought to see whether they are really marked "100 E.F. 8." For while the result of various purchases of 8-candle 100-volt Edison-Swan lamps during the past three years has always resulted in lamps marked "100 E.F. 8" being sent us, although the marking on the lamps was never specified by us, a recent batch of lamps that we have received contained among them certain lamps marked "100 B. 8," which not only differed in the marking but also in the filament being of a simple horse-shoe shape, and not with a loop at the top as in the case of the other lamps. And, on testing these Edison-Swan B lamps, we were surprised to find that with no one of them, when run at 100 volts, did the watts per candle exceed 3·9, and in some cases the watts per candle were as low as 3·01. We have not, however, had these B lamps for a sufficiently long time in our possession to be able to express any opinion about their life-history.

DISCUSSION.

Professor RÜCKER asked if it made any difference to the life of a lamp whether it were kept running continuously until the fibre broke, or were run for periods of a few hours, alternating with intervals of rest. The latter case would more nearly correspond with the conditions obtaining in practice.

Professor AYRTON replied that the lamps were kept running during the night, and were disconnected during the day.

XXXIX. *The Tin-Chromic Chloride Cell.*

By S. Skinner, *M.A.**

A cell consisting of a tin and platinum couple in a solution of the green chromic chloride was described by W. E. Case in the Proc. R. S. 1886, p. 345. The tin is dissolved by the chromic chloride at a high temperature only, and when the solution is cooled the tin is precipitated. The chemical changes are represented by the following statement:—

$$Cr_2Cl_6 + Sn \rightleftharpoons SnCl_2 + 2CrCl_2.$$

As the reaction is reversed on cooling, the cell has the interesting feature that at the end of a hot and cold cycle it is in the same chemical condition as it was at the commencement. It thus offers a method of deriving electrical energy directly from heat. The author of the account gives a curve of electromotive force, and finds that it is zero at 60° F., and increases to about $\frac{1}{4}$ volt at 200° F. I shall show that the E.M.F. is not zero at the ordinary temperature, but is about $\frac{1}{2}$ volt; however, the cell will not give any current at these temperatures on account of polarization. It appears that the curve given by Mr. Case is not an E.M.F. curve, but one which was probably obtained by using a wire voltmeter, and therefore really represents the current the cell is capable of producing.

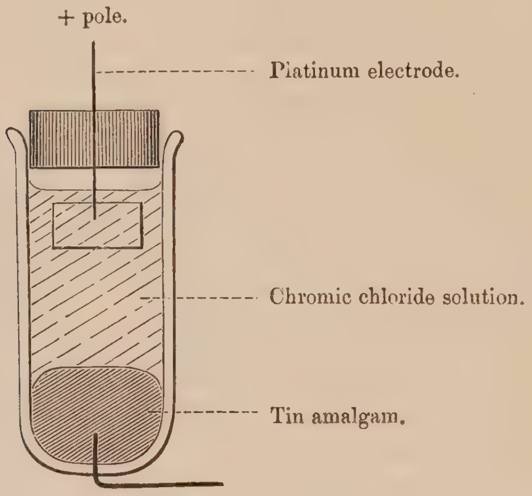
The tin is precipitated in small crystals from the cooling solution of $CrCl_2$ and $SnCl_2$, and does not then form a satisfactory electrode. I have therefore arranged the cell with an amalgam of tin in place of the solid rod. The precipitated crystals fall into the mercury and dissolve so as to reconstitute a suitable electrode. My construction of the cell is very much like that of a Clark cell.

A test-tube with a platinum wire through the base has fluid amalgam in it, and this is covered with a solution of pure Cr_2Cl_6, made by dissolving violet sublimed Cr_2Cl_6 in water with the aid of a fragment of tinfoil. A platinum plate and wire form the positive pole of the cell.

---

* Read February 8, 1895.

Connecting such a cell at 15° C. with a galvanometer, there is a sudden deflexion which very rapidly becomes less until some small steady value is reached. On warming the cell the deflexion increases until it is relatively large. These observations show that the cell cannot produce a continuous current of any magnitude at low temperatures, but at high temperatures it does.



If the E.M.F. of the cell be measured on a potentiometer, or by means of a ballistic galvanometer and condenser, by either of which methods the cell is not called on to produce a current, it is found that the E.M.F. at all temperatures is approximately $\frac{1}{2}$ volt, and that the E.M.F. is slightly less at the boiling-point of water than at the ordinary temperature.

The explanation of the results is not difficult. The cell polarizes very rapidly at low temperatures, and the opposing E.M.F. of polarization increases so rapidly and so largely that almost at the moment of connexion the effective E.M.F. becomes zero. The cell behaves like a condenser which is connected to a battery through a very high resistance. Such a condenser would discharge itself when its plates were connected, but when they were isolated again it would slowly become charged by the battery through the high resistance.

At the high temperature the polarization is very largely reduced, and the cell will produce a continuous current.

Another interesting feature of the cell is that it may be used as the mechanism of a heat-engine for the production of work, and we can trace in it the complete cycle of Carnot. Let the cell be placed in a hot chamber, and work may be derived from it until all the Cr_2Cl_6 or the tin is used. Then let the cell be placed in a cold chamber, it will give up heat, and becomes restored to its original chemical condition.

Measurements of the electromotive force of two cells are given in the following tables. The first cell contained tin-amalgam, and the second cell contained a tin rod. Both cells had not been used for producing current within the 24 hours immediately preceding the measurements.

Cell No. 1. Tin-amalgam.

Temperature.	E.M.F.
15·5° C.	·44 volt.
20·5	·45
49·0	·43
75·0	·41
93·0	·40
96·0	·40
97·0	·40
20·0	·44

Cell No. 2. Tin rod.

Temperature.	E.M.F.
16°	·52 volt.
30°	·52
97°	·45

Connexion was made and a current allowed to flow for 1 minute, and then the cell was allowed to rest for 1 minute :

97°	·08 volt.

At end of second minute :

97°	·11 volt.

At end of third minute :

97°	·11 volt.

These results showed that the cell had polarized, and was only slowly recovering its electromotive force.

When a solution of the green chromic chloride at the ordinary temperature has silver nitrate added to it, only two-thirds of the chlorine is precipitated. This, according to the theory of ionisation, indicates that only two atoms out of three act as negative ions, the other atom apparently being part of the positive ion. On the other hand, if a solution of chromic chloride near 100° be treated with silver nitrate, the whole of the chlorine may be precipitated. This indicates that at the higher temperature all the chlorine atoms behave as negative ions.

Taking this into account, the Grotthus chain representing the action of the cell about 15° must be as follows :—

$$\mathrm{Pt} \mid \mathrm{ClCrCl_2} \mid \mathrm{ClCrCl_2} \mid \mathrm{ClCrCl_2} \mid \mathrm{Sn},$$

becoming, after connexion,

$$\mathrm{Pt,ClCr} \mid \mathrm{Cl_2ClCr} \mid \mathrm{Cl_2ClCr} \mid \mathrm{Cl_2Sn}.$$

This view of the action leaves the ion ClCr polarizing the cell. Now if a depolarizer acts so as to remove this ion, the cell will go on producing a current. The excess of chromic chloride might perform this function, forming with this ion chromous chloride :

$$\mathrm{CrCl + CrCl_3 = 2CrCl_2}.$$

The behaviour of the cell shows that this does not take place readily.

A similar view of the action in the cell at about 100° indicates the presence of chromium ions as the polarizing agent. At this temperature there is not much polarization ; so that it appears the following chemical change takes place readily :

$$\mathrm{Cr + 2CrCl_3 = 3CrCl_2}.$$

DISCUSSION.

Prof. RÜCKER asked whether a change of polarization would explain the behaviour of the cell at different temperatures.

Prof. CAREY FOSTER asked whether the reversed chemical action on cooling from a high temperature were accompanied by a reversed E.M.F.

Mr. SKINNER said no ; the tin was precipitated throughout the solution, and not at the surface of the tin plate, so that no E.M.F. of the kind was to be expected.

Mr. APPLEYARD thought that Prof. Minchin had used tin chloride cells with two tin plates for electrodes, the cells only working when one plate was illuminated.

Mr. TROTTER wished to know whether heating the cell supplied energy to it, or simply removed an obstacle in the form of polarization.

Mr. SKINNER thought that heating acted by removing an obstacle.

Capt. ABNEY—And so doing work.

XL. *Note on a Simple Graphic Illustration of the Determinantal Relation of Dynamics.* *By* G. H. BRYAN[*].

IN the whole range of theoretical dynamics there is probably no theorem which is so difficult to fully grasp as the determinantal relation connecting the multiple differential of the initial coordinates and momenta of a system with that of its final coordinates and momenta. This relation, which may almost be regarded as the keystone to the Kinetic Theory of Gases, is conveniently written in the Jacobian form

$$\frac{d(p_1', p_2', \ldots, q_1', q_2', \ldots)}{d(p_1, p_2, \ldots, q_1, q_2, \ldots)} = 1,$$

where $p_1, p_2, \ldots$ are the generalized momenta corresponding to the generalized coordinates $q_1, q_2, \ldots,$ and unaccented and accented letters refer respectively to initial values and final values after a fixed interval of time t.

To my mind the difficulty of grasping this result arises from the want of simple graphical illustrations and verifications from first principles not involving the use of the Calculus. The following illustrative examples of its applications to systems with one degree of freedom have afforded me great assistance in understanding the theorem, and I trust that they may prove useful to others.

---

[*] Read April 26, 1895.

Consider a particle moving in the straight line OX (fig. 1) under any law of force. Let M be the position of the particle at any instant, and let the velocity of the particle at this instant be represented by the ordinate MP drawn at right angles to OX. Then, since the momentum is proportional to the velocity, the coordinates OM, MP represent the coordinate and momentum of the particle at the given instant, and we may call P the representative point.

Now let four such particles of equal mass be projected simultaneously, having the initial coordinates x and $x+\delta x$ and the initial velocities v and $v+\delta v$. The representative points will form a small rectangle P Q R S of area $\delta x \,.\, \delta v$.

Let P′ Q′ R′ S′ be the corresponding representative points at any subsequent instant t.

Then the determinantal relation asserts that the area of the small parallelogram P′ Q′ R′ S′ is equal to that of the rectangle P Q R S.

[Instead of taking four particles we might suppose the points P, Q, R, S to refer to the *same* particle projected with different initial conditions and allowed to move for a fixed time-interval t.]

This property may be verified from first principles in the following simple cases :—

Case I. *Let the motion be uniformly accelerated.* Then from the equations

$$v' = v + ft, \qquad x' = x + vt + \tfrac{1}{2}ft^2,$$

and the corresponding equations obtained by substituting $x+\delta x$ for x and $v+\delta v$ for v, it is easy to see (fig. 1) that the parallelogram P′Q′R′S′ has its base P′Q′ parallel to OX and equal to PQ or δx, and its altitude equal to PQ or δv Therefore

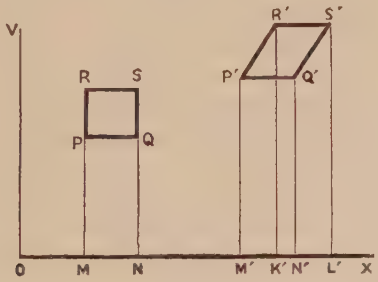
$$\text{area P}'\text{Q}'\text{R}'\text{S}' = \text{area PQRS}.$$

The parallelogram will, however, have undergone a shear, the points R, S having advanced beyond P, Q by an amount $(\text{M}'\text{K}' =)\, \delta v \,.\, t$. Hence

$$\cot \text{RPQ} = t\,\frac{\delta v}{\delta x},$$

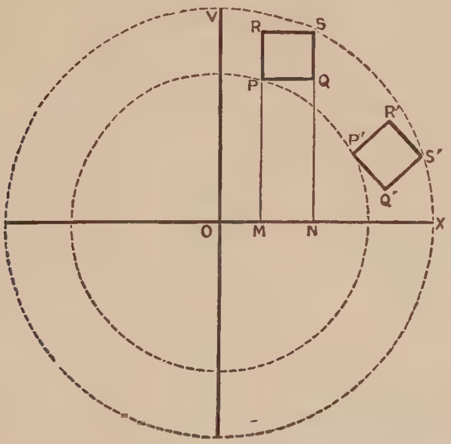
and is proportional to t. As the time increases, the diagonal $P'S'$ becomes more and more elongated, but the area of the parallelogram remains the same.

Fig. 1.



Case II. *Let the motion be simple harmonic,* the acceleration varying as the distance from a fixed point O (fig. 2). Then, by properly choosing the scale of representation of velocity, the representative points of different particles will all describe concentric circles about O with uniform angular velocity. Hence the figure PQRS will be brought into the position P′Q′R′S′ by rotating about O through a certain angle, and the areas of the two figures will of course be equal.

Fig. 2.



Case I. might be deduced as the limit of Case II. by (i.) reducing the scale of representation of velocity so that the circles become projected into ellipses ; (ii.) supposing the centre O to go off to infinity, so that these ellipses gradually become elongated into parabolas.

The case of a repulsive force varying directly as the distance would be a little more complicated ; and it therefore seems hardly worth while to give a proof for it, though the legitimacy of the corresponding inference for this case might be inferred by means of " imaginary projection." The theorem might possibly then be extended to the case of any variable law of force by dividing up the times, and therefore the corresponding spaces decribed, into elements so small that the force might be supposed to vary uniformly with the distance along OX in any single element. This is not put forward as a satisfactory proof, but then the object of this note was to show, not how to prove the theorem, but how to convince oneself of its truth after proving it by highly analytical methods. This I found hard in the case of systems like that of Case I., where a slight variation in the initial conditions (viz. the difference of velocity δv of the points M′K′) causes two such systems to separate indefinitely. I could not see how this was compatible with the multiple differential $(\delta x \, . \, \delta v)$ remaining constant till I had worked out the above explanation. It is a pity that systems with more than one degree of freedom could not be treated by this graphic method, but a similar objection applies equally to the graphic proof of the formula for uniformly accelerated motion of our text-books and to many other valuable illustrations of the principles of dynamics.

Discussion.

Dr. Stoney thought the arguments were based on actions depending on the distances of the molecules and the supposition that they were rigid. In his opinion events occur in nature which are not represented by this simple theory, and great reservation should be shown in accepting dynamical problems which leave out of account actions occurring between matter and the ether. In nature nothing was large and nothing was small except relatively. Even molecules might possess infinite detail of structure. Their interaction with the ether must be considered in any complete theory.

XLI. *On the Mechanical Analogue of Thermal Equilibrium between Bodies in Contact.* By G. H. BRYAN *and* LUDWIG BOLTZMANN*.

[Abstract.]

THE great disadvantage of the Kinetic Theory has been that it has not hitherto furnished a very satisfactory proof of the fundamental property of temperature, namely, that two bodies in contact are at *equal temperature* when neither gains or loses heat from the other.

In a medium composed of two or more different kinds of gas molecules mixed together, the conditions of equilibrium of kinetic energy involve Avogadro's well-known law†, namely, that the mean kinetic energies of translation of the different kinds of molecules shall be equal. From this we naturally infer that the quantity which represents *temperature* in the kinetic theory is proportional to the mean *vis viva* of translation. But our experimental knowledge of the properties of temperature is necessarily derived from observations of bodies which do *not* mix, and it is impossible to form a purely physical conception of the temperatures of two mixed gases apart from each other. We can only experiment on the temperature of the whole *mixture*.

It is therefore of great interest to devise a mechanical representation of the phenomena presented by two bodies between which transference of heat takes place by conduction, but whose molecules do not become indefinitely interdiffused. The system now to be described affords such a representation.

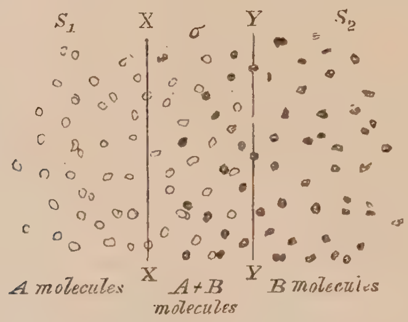
Let X and Y be two infinite parallel planes (or other surfaces) at a small distance apart, dividing space into three

---

* This paper is taken from a memoir by Prof. Ludwig Boltzmann and G. H. Bryan, communicated by Prof. Boltzmann to the Imperial Academy of Vienna, Dec. 13, 1894. Read at the meeting of the Physical Society, April 26, 1895.

† *Wien. Sitzungsber.* vol. lxiii. 1871, vol. lxvi. 1872, vol. xciv. 1886, vol. xcv. 1887.

regions, S_1, S_2, and σ, of which the region S_1 lies to the left of X, the region S_2 lies to the right of Y, and the region σ lies between the surfaces X, Y, and may be supposed to be very thin by supposing X, Y to be very near together.



Let there be two different kinds of molecules A, B, the former represented in the figure by light, and the latter by dark points, and let these molecules be acted on by different laws of force specified as follows :—

(i) The plane Y shall be supposed to repel the A molecules with a force which vanishes at all points on the left-hand side of X, but which becomes infinitely great as we approach the plane Y itself so as to prevent any of the A molecules from crossing beyond Y and passing into the region S_2. This force shall not act on the B molecules.

(ii) In like manner, the plane X shall be supposed to repel the B molecules with a force which vanishes at all points on the right-hand side of Y, but which becomes infinitely great as we approach the plane X itself, so as to prevent any of the B molecules from crossing beyond X and passing into the region S_1. This force shall not act on any of the A molecules.

Then in the region S_1 we have a gas composed only of A molecules, and in the region S_2 we have a gas composed entirely of B molecules. Between these regions there is the region σ containing a mixture of both kinds of molecules, and these molecules will collide with one another, and energy will thus be transferred from the molecules of one gas to those of the other.

The conditions of equilibrium of *vis viva* can be found by the usual methods, and the proof is applicable to the more general case where the A molecules are acted on by *any* external forces and the B molecules are acted on by any other external forces independent of the former forces, the two sets of molecules being mixed in those regions where the potentials of the two sets of forces are neither of them infinite. For this purpose it is convenient to use generalized coordinates.

Let $q_1, q_2, \ldots q_m$ be the generalized coordinates of an A molecule;

$p_1, p_2, \ldots p_m$, the corresponding generalized momenta;
T_1 its *vis viva*, χ_1 its potential energy;
$E_1 = T_1 + \chi_1$ its total energy.

Also let $Q_1, Q_2, \ldots Q_n$ be the coordinates of a B molecule;
$P_1, P_2, \ldots P_n$ the corresponding momenta;
T_2 its *vis viva*, χ_2 its potential energy;
$E_2 = T_2 + \chi_2$ its total energy.

Then, if χ_2 is a different function of $Q_1, Q_2, \ldots Q_n$ to what χ_1 is of $q_1, q_2, \ldots q_m$, the forces on the two kinds of molecules will be different.

Now it is proved* that if the number of A molecules whose coordinates and momenta be within the limits of the differential,

$$dp_1 \ldots . dp_m \, dq_1 \ldots . dq_m$$

is proportional to

$$Ae^{-h_1E_1}dp_1 \ldots . dp_m \, dq_1 \ldots . dq_m, \quad . \quad . \quad . \quad (1)$$

this distribution is permanent in the absence of collisions between the molecules, and is also unaffected by collisions between two A molecules.

Similarly if the B molecules are distributed with frequency proportional to

$$Be^{-h_2E_2}dP_1 \ldots . dP_n \, dQ_1 \ldots . dQ_n, \quad . \quad . \quad . \quad (2)$$

this distribution is stationary in the absence of collisions between the molecules, and is unaltered by collisions between two B molecules.

---

* *Wien. Sitzungsber.* vol. lxxii. 1875, vol. lxxviii. 1878, vol. xcvi. 1887.

Lastly, we must consider the effect of collisions between an A molecule and a B molecule. Now if the time of duration of a collision is infinitely short, the coordinates of the colliding molecules are the same at the beginning and end of a collision. And if we consider only collisions between pairs of molecules which are in a given configuration so that the coordinates of the molecules have given values, the momenta of the colliding molecules will be distributed with frequencies respectively proportional to

$$A_1 e^{-h_1 T_1}\, dp_1 \ldots . dp_m,$$

and

$$B_1 e^{-h_2 T_2}\, dP_1 \ldots . dP_m,$$

where A_1 and B_1 are constants, the potential energies χ_1 and χ_2 being the same for all the molecules in the given configuration.

If, then, we write

$$f = A_1 e^{-h_1 T_1},\ F = B_1 e^{-h_2 T_2},$$

and if f', F' be the values of the corresponding quantities after the collision, it is proved by Dr. Boltzmann * that

$$fF = f'F'\ ; \quad \ldots\ldots \quad (3)$$

and since finite forces have no effect during the infinitely small time of duration of a collision, the proof is independent of the finite forces between the molecules. The last equation gives

$$e^{-h_1 T_1 - h_2 T_2} = e^{-h_1 T_1' - h_2 T_2'},$$

that is

$$h_1 T_1 + h_2 T_2 = h_1 T_1' + h_2 T_2'.$$

But by the conservation of *vis viva*,

$$T_1 + T_2 = T_1' + T_2'.$$

Multiplying by h_2 and subtracting from the previous equation, we have

$$(h_1 - h_2) T_1 = (h_1 - h_2) T_1',$$

whence, since T_1, T_1' are not in general equal,

$$h_1 - h_2 = 0, \text{ or } h_1 = h_2. \quad \ldots\ldots \quad (4)$$

---

* *Wien. Sitzungsber.* vol. lxvi. 1872, last part.

The mean *vis viva's* of the A and B molecules are $3/2h_1$ and $3/2h_2$ and are therefore equal.

In my Report to the British Association I suggested that the distribution of a large number of molecules of the same or different kinds in which the coordinates (q) and momenta (p) are so arranged that the number of molecules in the neighbourhood of any given state is proportional to

$$e^{-hE}dp_1 \dots dp_n\, dq_1 \dots dq_n, \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

h being the same for all kinds of molecules, be called *The Boltzmann-Maxwell Distribution*, the law which asserts the permanency of the Boltzmann-Maxwell distribution in any particular case being called *The Boltzmann-Maxwell Law.*

If these names be adopted, we have the result that the Boltzmann-Maxwell Law holds good for a mixture of different kinds of gas molecules, even when the forces which act on the molecules of one gas are entirely different from those which act on any other gas. The reasoning applies equally when there are any number of different kinds of molecules.

The densities of the A and B molecules are respectively proportional to

$$Me^{-h\chi_1} \text{ and } Ne^{-h\chi_2}, \quad . \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

where M and N are certain constants depending on the total numbers of respective molecules.

Hence if $\chi_1 = \infty$ over any region, that region contains only B molecules, and if $\chi_2 = \infty$ the region contains only A molecules, and the two kinds of molecules are mixed together in regions where χ_1 and χ_2 are both finite.

Instead of assuming a field of force of the kind considered above, we might assume the A molecules to be positively electrified and the B molecules to be negatively electrified, the planes X, Y being kept at a constant difference of potential. If this difference of potential be V and if the charges on the respective molecules are $q_1 - q'$, the densities of the A molecules in the regions S₁ S₂ will be in the ratio of $1 : e^{-hqV}$, and the densities of the B molecules in the ratio of $e^{+hq'V} : 1$ and by making V sufficiently great we shall make e^{-hqV} and $e^{-hq'V'}$ very small, and the gases in the regions S₁, S₂ will be very nearly pure.

If collisions are replaced by encounters in which the molecules attract or repel one another with finite forces during a finite time, the same result may be proved by a method indicated by Prof. Boltzmann in his recent communication to the British Association, entitled "On the Application of the Determinantal Relation to the Kinetic Theory of Polyatomic Gases"*.

For the determinantal relation between the multiple differentials of the coordinates and momenta of a conservative dynamical system at the beginning and end of any interval of time $t'-t$ is of the form

$$\frac{\partial(p_1', \ldots p_m', q_1', \ldots q_m')}{\partial(p_1, \ldots p_m, q_1, \ldots q_m)}=1. \quad . \quad . \quad . \quad (6)$$

(1) If we apply this relation to a single molecule of gas moving about freely or in a field of external force, the relation will apply so long as the molecule considered does not encounter or collide with other molecules; and the possible laws of permanent distribution of the coordinates and momenta among a large number of such molecules may now be established thus:—

We know that for any one molecule the total energy is independent of the time or

$$E_1=\text{constant},$$

and the determinantal relation shows that the multiple differential

$$dp_1, \ldots . dp_m dq_1, \ldots . dq_m$$

is also independent of the time.

Therefore, if the law of distribution be such that the number of molecules included within the limits of the multiple differential at any instant of time (t) is

$$f_1(E_1)dp_1 \ldots . dq_m, \quad . \quad . \quad . \quad . \quad . \quad (7)$$

where f_1 denotes any function whatever, the same law will hold good at any subsequent instant of time (t').

In particular, taking $f_1(E_1)=e^{-hE_1}$, we conclude that in the absence of such encounters any distribution determined by the expression (1) of the A molecules will be permanent, and a similar conclusion holds with respect to the distribution (2) of the B molecules.

---

* Oxford Report, p. 102.

(2) We may take as our dynamical "system" a pair of molecules of the same or different kinds in the course of a binary encounter, it being assumed that the intermolecular forces remain finite during encounter, and that at each instant there are sufficient encounters of the same kind to give rise to a law of permanent distribution among the encountering sets of molecules. Here the multiple differential will have to include all the coordinates and momenta of all the molecules in the group considered. Hence if E is the total energy of a pair of A and B molecules in the course of an encounter, any distribution of the pairs of molecules of the form

$$f(E)dp_1 \ldots dp_m dq_1 \ldots dq_m dP_1 \ldots dP_n dQ_1 \ldots dQ_n$$

will be permanent so long as the molecules of any one pair do not encounter any molecules not in that pair.

But in a gas each molecule will encounter various molecules in succession, so that the same pair of molecules cannot be considered permanently as a system apart from the rest. From this we find at once that if the frequency of distribution f is a function of energy alone, it *must* be of the well-known form

$$f=e^{-hE}.$$

For *before* two molecules encounter each other, the frequency of distribution of the coordinates and momenta of one cannot depend on the coordinates and momenta of the other. Hence if f_1, f_2 denote the frequencies of distribution of the two molecules just before the encounter,

$$f_1 \times f_2 = f(E).$$

Now we may write

$$E = T_1 + T_2 + \chi_1 + \chi_2 + \chi_{12},$$

where T_1 T_2 are the kinetic energies of the two molecules, χ_1 χ_2 are the potential energies of the molecules due to the field of force, χ_{12} their mutual potential energy during the encounter.

But the same law must hold just before the encounter as during it, and just before the encounter χ_{12} is zero, so that

$$E = E_1 + E_2,$$

where E_1 E_2 are the separate energies of the molecules ; and the resulting relation

$$f_1 \times f_2 = f(E_1 + E_2). \quad . \quad . \quad . \quad . \quad . \quad . \qquad (8)$$

can only be satisfied by

$$f_1 = e^{-hE_1}, \ f_2 = e^{-hE_2}, \ f = e^{-hE}.$$

Hence before and after the encounter the molecules have their coordinates and momenta distributed with frequencies proportional to e^{-hE_1} and e^{-hE_2} respectively. But *during* an encounter the frequency of distribution of *all* the coordinates and momenta of the pair or group is proportional to e^{-hE}, and the two encountering molecules cannot be considered separately.

For a pair of molecules we may write the function

$$\begin{aligned} f &= e^{-h(T_1+\chi_1+T_2+\chi_2+\chi_{12})} \\ &= e^{-hT} \times e^{-hT_2} \times e^{-h(\chi_1+\chi_2+\chi_{12})}. \quad . \quad . \quad . \qquad (9) \end{aligned}$$

This shows that for any given *configuration* the *momenta* of the molecules denoted by the suffixes 1, 2 are separately distributed with frequencies proportional to e^{-hT_1} and e^{-hT_2} respectively. The distribution of the *coordinates* of one molecule is not, however, independent of the position of the other owing to the presence of the factor $e^{-h\chi_{12}}$. When the encounter is over χ_{12} vanishes, this factor disappears, and the distributions of the coordinates of the two molecules become independent of each other, being of the forms (1) (2).

And since χ_1 and χ_2 may be of any forms whatever, and may be entirely different, the reasoning is immediately applicable to systems such as that which forms the subject of the present paper. Wherever χ_1 or χ_2 becomes infinite the number of molecules becomes zero, so that encounters do not there occur.

Similar reasoning holds good for encounters between two A molecules or between two B molecules or for simultaneous encounters between any number of molecules, provided that the encounters considered are sufficiently frequent to *have* a law of distribution.

And of course collisions can be treated as a limiting case of encounters.

The above brief investigation shows the advantage of applying the determinantal relation to encounters as well as to the free motion of molecules between encounters. With this method it is not necessary to start as Prof. Boltzmann previously did, by *assuming* the frequency of distribution to be determined by a function f of the form e^{-hE}, but if we merely assume f to be any function of the energy we may deduce that the form $f(E)=e^{-hE}$ is *necessary* as well as *sufficient*.

XLII. *Note on a Neglected Experiment of* Ampère.

By SILVANUS P. THOMPSON[*].

In the year 1822 Ampère, being at Geneva, showed to De la Rive in his laboratory a number of his now classical experiments on the actions of conductors carrying currents upon other conductors and upon magnets. These are recounted by A. De la Rive in the *Annales de Chimie et de Physique*, xxi. p. 24 (1822).

Amongst these experiments there is one that has almost been forgotten, but which, had it been followed up, would assuredly have led Ampère to anticipate by some years the great discovery of Faraday as to the induction of currents.

The experiment was first described by Ampère in October 1821, in a letter[†] to Van Beck. It had been tried in the preceding July. The following is Ampère's own first description of it:—

"Ce que cette expérience prouve directement, c'est que la proximité d'un courant électrique n'en excite point, par influence, dans un circuit métallique de cuivre, même dans les circonstances les plus favorables à cette influence. Voici l'expérience que je fis alors pour m'en assurer : je formai avec un long fil de cuivre A B C D E F [fig. 1], revêtu d'un ruban, une spirale B C D E dont les tours étaient séparés les

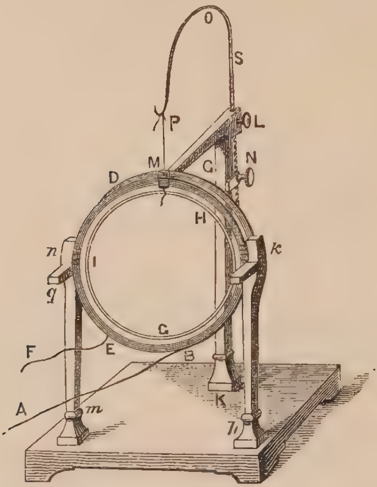
---

[*] Read April 26, 1895.

[†] *Journal de Physique*, t. xciii. p. 447, Oct. 1821. Reprinted at p. 212, vol. ii. of the 'Collection de Mémoires relatifs à la Physique, publiés par la Société française de Physique,' 1885.

uns des autres par la soie de ce ruban ; je disposai cette spirale, comme on le voit dans la fig. 1, sur le pied en bois *h k m n* ; les deux extrémités A et F de ce fil communiquaient avec celles de la pile de douze triades d'un pied carré, dont je me suis servi pour la plupart de mes expériences. La partie supérieure de cette spirale était traversée par un petit tube de verre M, passant entre les spires qui se trouvaient les unes en avant et les autres en arrière de ce tube ; un fil métallique très-fin le traversait sans en toucher les parois intérieures; il était attaché par un bout à la potence K S O P, qu'on faisait monter ou descendre à volonté en tournant le bouton N, et qu'on arrêtait à la hauteur convenable en serrant la vis de pression L ; le cercle mobile G H I était suspendu au bout de ce fil, de manière à être concentrique à la spirale, situé dans le même plan, et très près des spires dont elle se composait. Le pied *h k m n* portait en outre deux petites règles *k p*, *n q*, sur lesquelles on pouvait appuyer les aimants qui devaient agir sur le cercle mobile. Cette disposition m'a paru la plus convenable pour exciter dans ce cercle des courants électriques par influence, si cela était possible ; mais en le présentant à l'action d'un fort aimant,

Fig. 1.



je n'ai pas aperçu qu'il prit aucun mouvement, malgré la grande mobilité de ce genre de suspension."

The experiment of July 1821, being thus unsuccessful, was repeated in 1822 at Geneva, using a more powerful horseshoe magnet lent by Pictet. It is described by De La Rive* in the following terms:—

" La seconde expérience consiste dans l'influence qu'éprouve une lame de cuivre pliée en cercle de la part d'une ceinture de forts courans électriques au milieu desquels elle est suspendue, et qui l'entourent sans la toucher. Cette influence, que M. Ampère avait d'abord crue nulle, a été, à Genève, constatée par lui-même d'une manière très-précise. En présentant à un côté de cette lame un aimant en fer à cheval, très-fort, on l'a vue tantôt s'avancer entre les deux branches de l'aimant, tantôt au contraire en être repoussé, suivant le sens du courant dans les conducteurs environnans. Cette expérience importante montre donc que les corps qui ne sont pas susceptibles, au moyen de l'influence des courans électriques d'acquérir une aimentation permanente, comme le sont le fer et l'acier, peuvent du moins acquérir une sorte d'aimentation passagère pendant qu'ils sont sous cette influence †."

This note, which is textually repeated at p. 285 of Ampère's 'Recueil d'Observations,' is entirely vague on the crucial point whether the attractions and repulsions observed occurred only at times when the current was varying. By reprinting it textually (even the footnote about the instrument, which, however, he changed into the first person and signed with his initial "A"), Ampère accepted De la Rive's version and explanation of the Geneva experiment. Nevertheless a second version was given by Ampère himself* twelve days later on his return to Paris. This document lay unpublished in the Ampère manuscripts belonging to the Académie des Sciences until 1885. It reads as follows :—

---

* Read to the 'Société de Physique et d'Histoire naturelle de Genève on Sept. 4, 1822; published first in the *Bibliothèque Universelle*, t. xxi. p. 29 (1822), then in the *Annales de Chimie et de Physique*, t. xxi. p. 47 (1822); reprinted by Ampère at p. 262 of his 'Recueil d'Observations électrodynamiques,' 1822, and again in the 'Collection de Mémoires,' t. ii. p. 328 (1885).

† "L'instrument dont M. Ampère s'est servi pour cette expérience est le même qu'il avait employé lorsqu'il l'essaya au mois de juillet 1820; il a été décrit et figuré dans le *Journal de Physique*." [This is a reference to *Journal de Physique*, xciii. p. 447, Dec. 1821, with a plate showing the apparatus. The same apparatus is depicted in fig. 17, plate vi., of Ampère's 'Recueil d'Observations électrodynamiques' (1822); and is described on p. 170 of that work. There is a discrepancy about the dates; July 1820 is here given, whereas Ampère's first date was given as July 1821.—S. P. T.]

"La troisième expérience avait pour objet de savoir si l'on peut produire un courant électrique par l'influence d'un autre courant. Il y a plus d'un an que je l'avais tentée, sans succès, avec l'appareil representé [fig. 1]; mais j'ai réussi avec un appareil absolument semblable, en employant l'excellent aimant en fer à cheval du musée de Genève, que m'avait procuré M. le professeur Pictet. Voici la description de cette expérience." [Here follows the description of the apparatus, word for word almost the same as that above in the description of the unsuccessful experiment of July 1821.] "Le circuit fermé placé sous l'influence du courant électrique dédoublé, mais sans aucune communication avec lui, a été attiré et repoussé alternativement par l'aimant, et cette expérience ne laisserait, par consequent, aucun doute sur la production des courants électriques par influence, si l'on ne pouvait soupçonner la présence d'un peu de fer dans le cuivre dont a été formé le circuit mobile. Il n'y avait cependant aucune action entre ce circuit et l'aimant avant que le courant électrique parcourût la spirale dont il était entouré ; c'est pourquoi je regarde cette expérience comme suffisante pour prouver cette production ; je me propose, néanmoins, pour prévenir toute objection, de la répéter incessament, avec un circuit formé d'un métal nonmagnétique très pur. Ce fait de la production de courants électriques par influence, très intéressant par lui-même, est d'ailleurs indépendant de la théorie générale de l'action électrodynamique."

There is a discrepancy between the first and second versions, in that while De la Rive says that the attractions and repulsions were in correspondence with the sense of the current in the coil (which we know could not be the case), Ampère says nothing about reversal of the current. As he attributed the effect to the possible presence of iron, it is clear he was expecting an effect due to the continued pressure of the current, not an instantaneous effect at make or break. We know now that this must have been so, and that an unvarying current could have produced no such effects as those described. That this should have escaped the notice not only of Ampère, but also of so skilled an experimenter as De la Rive, is remarkable. But the explanation of the phenomenon, as being due to a temporary magnetization acquired by the non-magnetic metal, given by De la Rive, and accepted by Ampère, is still more strange. Had no suggestion ever been made that there might possibly be an induction of currents by the action of a magnet, an explanation which ascribed the effects to a sort of temporary magnetism might have been more reasonable. But Ampère had himself already been looking for a possible inductive effect; nor was he alone in the idea that such might exist. Fresnel had on November 6th, 1820, announced to the Academy of Sciences that he had decomposed water by means of a magnet which was laid motionless within a spiral of wire. Emboldened by this announcement, Ampère remarked that he too had noticed something in the way of production of currents from a magnet. But before the end of the year these statements were withdrawn by their authors. Fresnel wrote* to the *Annales de Chimie* explaining the matter. He had surrounded a bar-magnet of steel with a spiral of iron wire, the ends of which dipped into water; and what he had announced on November 6th was that he had found one end of the iron wire to be discoloured and oxidized, while the other became covered with minute bubbles. He now finds that the announcement was premature, that the effects were not sustained by repeating the experiment, and, further, he says he does not believe in the success of Ritter's much earlier attempts to decompose water by a magnet. On behalf of M. Ampère, he added that the latter had indeed found little movements of a magnetic needle by bringing near it a circuit of copper wire (*laiton*) of which a portion was coiled in a spiral around a magnet, but that these movements were not repeated in any constant manner. Further, that these movements were, moreover, so feeble that Ampère would not have published the experiments if the success of Fresnel's, which he thought certain, had not persuaded him that these small agitations were occasioned also by an electric current resulting from the action of the magnet on the spiral in which it was enveloped.

---

* Memoir presented to the Académie des Sciences, September 16, 1822 ; published for the first time in the 'Collection des Mémoires' by the 'Société française de Physique' (1885), t. ii. p. 329.

---

* *Ann. Chim. Phys.* xv. 1820, pp. 219–222, "Note sur des Essais ayant pour but de décomposer l'eau avec un aimant."

This having occurred in 1820, it is clear that when making the Geneva experiment in 1822 Ampère must have had before him the possibility of induced currents, and chose rather the explanation of a temporary magnetism conferred on the copper loop.

Others in the meantime had tried to repeat Fresnel's observation, and found it erroneous.

Gilbert*, after giving an abstract of Fresnel's reputed discovery, says that he repeated the experiment without finding any discoloration of the iron wire, and concluded that the announcement was premature. Similar conclusions were arrived at by Pohl†.

A year or two later, when Arago's rotations were attracting the attention of experimenter, Becquerel ‡ investigated the supposed magnetism of bodies by taking small pieces of them, which he hung within a multiplier-coil of wire in place of the usual magnetic needle, and then turning on a current observed whether they moved or not. He found signs of magnetic action in needles made of peroxide of iron, copper, wood, and even shellac. After narrating his own experiments, he alluded to the Geneva experiment of Ampère, on p. 272, in the following terms :—

"Il résulterait de cette expérience, vu l'action semblable exercée par les deux poles de l'aimant en fer à cheval sur une même portion du circuit, que l'influence du courant électrique aurait développé dans la lame un autre courant électrique, tel qu'on en observe dans un fil métallique qui communique avec les deux poles d'une pile voltaique ; mais

---

* Gilb. *Ann.* xlvi. p. 410.

† Oken's *Isis*, 1822, pt. iv. p. 407. Also see remarks signed "P" at the end of an article by Savary in Pogg. *Ann.* viii. p. 368 (1826).

‡ *Ann. Chim. Phys.* xxv. p. 269.

M. Ampère s'est assuré depuis qu'il n'en est pas ainsi." What steps Ampère had in the meantime taken to assure himself that induction currents did not exist, Becquerel did not state, however.

In 1831 came Faraday's discoveries of the induction of currents by magnets, of the induction of currents by other currents, and of the cause of Arago's rotations. A group of notes* on these discoveries is to be found in December 1831 in the *Annales de Chimie.* It is curious to note the change of views. Becquerel and Ampère's communication to the Academy of January 23, 1832, appears along with abstracts of Faraday's work, and with an account of the experiments of Nobili and Antinori. There is an epitome of facts observed by Becquerel, and another of things to be looked for, by Ampère. This is followed by the following :—" Expériences sur les Courans électriques produits par l'influence d'un autre Courant," par M. Ampère. This article gives a third version of the Geneva experiments.

" Pendant mon séjour à Genève au mois de septembre 1822, M. Auguste de la Rive voulut bien m'aider dans des expériences que je désirais de faire sur la production d'un courant électrique par l'influence d'un autre courant.... Nous présentions à ce cercle un fort aimant en fer à cheval, de manière qu'un de ses poles se trouvait au dedans et l'autre au dehors du cercle. Dès que nous faisions communiquer avec la pile les deux extrémités du fil conducteur le cércle était attiré ou repoussé par l'aimant, suivant le pole qui répondait à l'intérieur du cercle : ce qui démontrait l'existence du courant électrique qui y était produit par l'influence du courant du fil conducteur. La découverte que vient de faire M. Faraday des courans électriques produits par l'influence d'un aimant, courans qu'avait obtenu Fresnel en 1820, mais qu'il n'avait pas cru suffisamment constatés par ses expériences, m'a porté naturellement à employer le galvanoscope multiplicateur, dont l'illustre chimiste anglais a fait usage, pour constater de nouveau et étudier dans toutes ses circonstances la production d'un courant électrique par un autre courant."

---

* *Ann. Chim. Phys.* xlviii. 1831, pp. 405–428; see also Pogg. *Ann.* xxiv. 1832, p. 612, and particularly p. 614.

Ampère seems to have considered that the oxidation at first alleged by Fresnel was caused by induction currents arising from the diurnal variations of the magnetism of the stationary magnet. But it is evident that the electromotive forces due to any such cause would be of an order of magnitude utterly inadequate for the purpose. Further, as such currents must necessarily have been in alternate directions during the rise and fall of temperature, the total chemical action at the end would in no way depend upon the intermediate charges, but only upon the difference between the initial and final temperatures. Hence the total electromotive impulse tending to chemical action must have been infinitesimal compared with that due to simply removing the magnet once from the circuit! The third version differs from the former in describing the position of the magnet, and saying that the magnet (which in the original Ampère experiment was brought up after the current had been turned on) was placed in position *before* the circuit was completed.

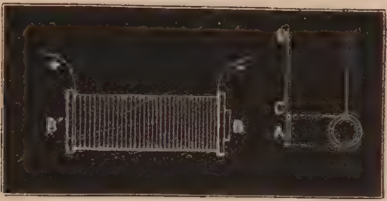
From that time forward Ampère's experiment seems to have passed into oblivion. One reference to it, however, appeared in 1872, which gives a fourth version, differing not only from the three former, but accompanied by a picture and description of a very different form of apparatus. This description, from the pen of the usually accurate M. Verdet, is to be found at p. 357 of his well-known *Conférences de Physique*. It runs as follows:—

"209. *Expérience d'Ampère et De la Rive.*—Longtemps avant l'époque où Faraday fit la découverte de l'induction, Ampère et De la Rive * avaient fait une expérience relative à ces phénomènes et qu'ils n'avaient pas comprise. Ces physiciens cherchaient s'il y avait une action des courants sur des conducteurs placés à distance, par analogie avec les effets d'influence de l'électricité ordinaire; ils entreprirent une série d'expériences avec l'idée préconçue que le phénomène produit par le passage du courant dans un conducteur voisin serait permanent, c'est à dire persisterait pendant tout le temps que le courant traverserait le conducteur; ayant au contraire observé un phénomène instantané, ils regardèrent ce résultat comme un fait singulier ne méritant pas une étude ultérieure. Voici en qui consistait leur expérience : un fil fin de cuivre enroulé en anneau A [fig. 2] était suspendu à un fil de soie

---

* *Bibliothèque Universelle*, septembre 1822, et *Annales de Chimie et de Physique* [2], t. xxi. p. 47 (1822), et t. xxv. p. 272 (1824).

Fig. 2.



sans torsion OC, devant la base d'un électro-aimant BB′, de manière que les plans des spires de l'electro-aimant fussent parallèles au plan de l'anneau. A l'instant où le courant était lancé dans l'électro-aimant, l'anneau était repoussé ; mais cette déviation ne persistait pas, et bientôt le fil revenait rigoureusement à la verticale. Si l'on interrompait le courant, on observait une attraction aussi peu persistante que la répulsion."

The anachronism of representing a soft-iron electromagnet as having been used in 1822 is the strangest part of this description. But the experiment, as described by Verdet, is of interest as being a sort of forerunner of the actions observed in 1884 by Boys*, and in 1887 by Elihu Thomson.

I have repeated the experiment of Ampère in the form originally shown to De la Rive. It is quite easy of performance : but the relatively great moment of inertia of the copper circle masks the purely transitory effect of the impulse which the ring receives each time the current is turned on or off in the outer coil.

---

* "A Magneto-electric Phenomenon." Proc. Phys. Soc. vol. vi. p. 218, 1884 ; Phil. Mag. [5] xviii. p. 216.

XLIII. *A Theory of the Synchronous Motor.*

By W. G. Rhodes, *M.Sc.*[*]

1. Several foreign writers, notably Steinmetz[†], have given theories of the synchronous motor, but most of them, by failing to see how the analysis could be simplified, add to the difficulties of the theory by mathematical intricacies which are apparently quite unnecessary. The author offers the following attempt to present a theory of the synchronous motor in as simple a way as possible, and as the mathematics for the most part consists of simple algebra, the difficulties are reduced to a physical conception of the subject. Many of the results have already been obtained, and the part for which the author chiefly claims originality is the method of attacking the problem.

2. We consider the case of an alternating-current machine whose field is excited by a direct current, while a simple alternating current passes round the armature.

Let p = output of motor ;
c = virtual value of armature current ;
R = resistance of armature ;
E = virtual value of impressed E.M.F. ;
e = ,, ,, counter E.M.F. ;
L = coefficient of self-induction of armature ;
n = frequency of armature current ;
I = impedance of armature = $\{\mathrm{R}^2+(2\pi n\mathrm{L})^2\}^{\frac{1}{2}}$;
S = reactance = $2\pi n\mathrm{L}$;
ψ = phase-difference between c and E ;
ϕ = ,, ,, c and e ;
θ = ,, ,, c and $\mathrm{I}c$.

Then the input $= p+c^2\mathrm{R}$;

and also $= c\mathrm{E}\cos\psi$;

therefore
$$p+c^2\mathrm{R} = c\mathrm{E}\cos\psi.$$

---

[*] Read April 26, 1895.

[†] Trans. Am. Inst. Elec. Eng., December 1894.

Solving for c we get

$$c = \frac{\mathrm{E}}{2\mathrm{R}} \cos \psi \pm \frac{1}{2\mathrm{R}} \sqrt{\{\mathrm{E}^2 \cos^2 \psi - 4p\mathrm{R}\}}. \quad . \quad . \quad (1)$$

Since c is always real, we must have

$$\mathrm{E}^2 \cos^2 \psi \geqq 4p\mathrm{R} ;$$

therefore the maximum value of p is

$$p = \frac{\mathrm{E}^2}{4\mathrm{R}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

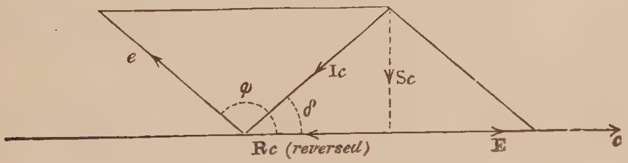
This occurs when $\psi = 0$; that is, when the current and the impressed E.M.F. are in phase with each other.

3. We notice that the maximum output is the same as the maximum energy which can be given to an external circuit by a generator of constant E.M.F., E. From (1) we get the corresponding value of the current

$$c = \frac{\mathrm{E}}{2\mathrm{R}}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

To find the corresponding value of e we notice that E, e, and Ic (the resultant of Sc and Rc reversed) are in equilibrium amongst themselves ; so that taking components of these along and at right angles to the direction of E, we have

Fig. 1.



$$\left.\begin{aligned} -e\cos\phi &= \mathrm{E} - \mathrm{R}c \\ \text{and} \qquad e\sin\phi &= \mathrm{S}c \end{aligned}\right\} ;$$

$$\left.\begin{aligned} \text{therefore} \qquad e\cos\phi &= 2\mathrm{R}c - \mathrm{R}c = \mathrm{R}c \\ \text{and} \qquad e\sin\phi &= \mathrm{S}c \end{aligned}\right\} \text{from (3).}$$

Squaring and adding, we get

$$e^2=(R^2+S^2)c^2=I^2c^2,$$

therefore

$$e=Ic=\frac{IE}{2R}. \qquad (4)$$

Also, by division,

$$-\tan\phi=\frac{S}{R}=\tan\theta \text{ (see fig. 1).}$$

4. We thus find that when working at maximum output:—

(1) The impressed E.M.F. is in phase with the current in the armature.

(2) The maximum output is $p=\frac{E^2}{4R}$.

(3) The corresponding current in armature is $c=\frac{E}{2R}$.

(4) The corresponding counter E.M.F. is $e=\frac{IE}{2R}$.

(5) The angle of phase between the armature-current and the E.M.F. necessary to overcome the resistance and self-induction of the armature is equal and opposite to the angle between the current and the counter E.M.F.

(6) Also from (4) we see that

$$e \gtreqless E \text{ according as } I \gtreqless 2R,$$

$$\text{that is according as } (2\pi nL)^2+R^2 \gtreqless 4R^2,$$

$$\text{,,} \qquad \text{,,} \qquad L^2 \gtreqless \frac{3R^2}{4\pi^2n^2},$$

$$\text{,,} \qquad \text{,,} \qquad L \gtreqless \frac{R\sqrt{3}}{2\pi n}.$$

Running Light.

5. We have

$$\left.\begin{aligned} p+c^2R&=cE\cos\psi \\ \text{and} \qquad p&=ce\cos\phi \end{aligned}\right\}.$$

If we neglect the friction of the bearings &c., we may, in this case, put $p=0$; we then have

$$\phi=\pm\frac{\pi}{2}$$

and

$$cR = E \cos \psi.$$

Hence the maximum value of c is (putting $\psi = 0$)

$$c = \frac{E}{R},$$

the same as would be produced by a constant E.M.F. E in a non-inductive circuit of resistance R.

Also putting $\psi = \pm \frac{\pi}{2}$, the minimum current is zero.

Now, from fig. 1, we get (of course E and c are not now in phase)

$$E^2 = e^2 + I^2c^2 + 2Ice \cos(\theta - \phi);$$

when $\phi = \pm \frac{\pi}{2}$, this becomes

$$E^2 = e^2 + I^2c^2 \pm 2Ice \sin\theta$$

$$= e^2 + I^2c^2 \pm 2Sce, \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

since $\sin\theta = \frac{S}{I}$.

The upper sign in (5) corresponds to the machine running as a generator, and the lower sign as a motor.

We also see from (5) that corresponding to $c = \frac{E}{R}$ we have

$$e = \mp \frac{ES}{R},$$

and, corresponding to $c = 0$, we have

$$e = \pm E.$$

Now, solving equation (5) as a quadratic in c we get

$$c = \mp \frac{eS}{I^2} \pm \frac{1}{I^2}\sqrt{(I^2E^2 - R^2e^2)}, \quad . \quad . \quad . \quad . \quad (6)$$

and, as c is real, we must have

$$I^2E^2 \geqq R^2e^2$$

or

$$IE \geqq Re;$$

therefore the maximum value of e is given by

$$e = \pm \frac{IE}{R}.$$

and the corresponding current is

$$c = \mp \frac{eS}{I^2}$$

$$= \mp \frac{SE}{RI}.$$

The equation

$$e^2 - 2Sce + I^2c^2 = E^2$$

is the characteristic curve of the motor running light. It may be written

$$e^2 - 2Sce + S^2c^2 + R^2c^2 = E^2$$

or

$$(e - Sc)^2 + R^2c^2 = E^2,$$

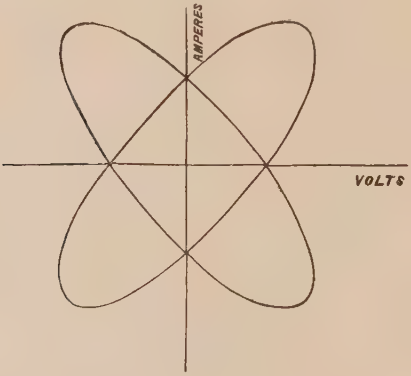
or

$$\frac{(e-Sc)^2}{E^2} + \frac{c^2}{\frac{E^2}{R^2}} = 1,$$

which is the equation to an ellipse having as conjugate diameters the lines

$$e - Sc = 0 \text{ and } c = 0.$$

Fig. 2.



Similarly, the equation

$$e^2 + 2Sce + I^2c^2 = E^2,$$

which refers to the generator, may be written

$$\frac{(e+Sc)^2}{E^2}+\frac{c^2}{\frac{E^2}{R^2}}=1,$$

also the equation to an ellipse. These ellipses are represented in fig. 2.

Minimum Current at Given Power.

6. We have

$$p+c^2R=Ec\cos\psi.$$

The current is a minimum when $\frac{dc}{d\psi}=0$. Now, differentiating with respect to ψ,

$$(2cR-E\cos\psi)\frac{dc}{d\psi}+Ec\sin\psi=0;$$

therefore, when $\frac{dc}{d\psi}=0$, we have

$$\sin\psi=0,$$

or

$$\psi=0;$$

that is, the current is a minimum when in phase with the impressed E.M.F., as is otherwise obvious. Putting, therefore, $\psi=0$, we have

$$p+c^2R=Ec. \qquad \text{(7)}$$

This curve is of the second degree in c and p, and is satisfied by the following system of points:—

$$(a)\ \left.\begin{aligned}c&=0,\\p&=0,\end{aligned}\right\}\qquad (b)\ \left.\begin{aligned}c&=\frac{E}{2R},\\p&=\frac{E^2}{4R}\end{aligned}\right\}\qquad (c)\ \left.\begin{aligned}c&=\frac{E}{R},\\p&=0.\end{aligned}\right\}$$

That the equation is satisfied by (a) is obvious, and we see that it is satisfied by the points (b) and (c) by writing it in the form

$$\left(c-\frac{E}{2R}\right)^2+\frac{p}{R}=\frac{E^2}{4R^2}.$$

7. Thus we see that the curve of minimum current at given power passes through the points of

- (*a*) zero current and zero power;
- (*b*) maximum power;
- (*c*) maximum current and zero power.

We notice that the maximum current at no load is $c=\frac{E}{R}$, whereas if the motor were at rest the current would be $c=\frac{E}{I}$; that is, the maximum current at no load is in all cases greater than the maximum current if the armature is at rest.

8. Again, from the equation

$$p+c^2r=cE\cos\psi$$

we have

$$\psi=\cos^{-1}\frac{p+c^2r}{cE},$$

therefore

$$\frac{d\psi}{dc}=\frac{c^2r-p}{c\sqrt{\{c^2E^2-(p+c^2r)^2\}}}$$

$$=0$$

when

$$p=c^2r.$$

ψ is then a maximum, and we see that the maximum difference of phase between the current and the impressed E.M.F. takes place when the electrical efficiency is $\frac{1}{2}$.

9. *Example.*—Suppose we have a 50 kilowatt motor driven by a 1000 volt generator, and suppose that $R=3$ ohms and $S=4$ ohms, so that $I=5$ ohms.

Then maximum output . . $=\frac{10^6}{12}=$ 83·3 kilowatts.

Corresponding current . . $=\frac{1000}{6}=$ 166·7 amperes.

" counter E.M.F. $=\frac{5000}{6}=$ 833·3 volts.

Maximum current running light $=\frac{1000}{3}=$ 333·3 amperes.

Corresponding counter E.M.F. $=\frac{4000}{3}=$ 1333·3 volts.

&c.

PHYSICAL SOCIETY OF LONDON.

ABSTRACTS OF PHYSICAL PAPERS

FROM FOREIGN SOURCES.

AUGUST 1895.

GENERAL PHYSICS.

541. *Methods of Investigating Elasticity.* **Cantone.** (Rend. Acc. Linc. 4. pp. 488–496, 1895.)—The study of elastic properties by the method of oscillations has led to results which are not in agreement with those obtained by the statical method, even if the same body is used in the two experiments. The dynamical results, which do not involve large deformations, are usually looked upon with more confidence. The author works out a method in which the two methods are used simultaneously. It is based upon the following considerations. It is possible that, as the torsion increases, a larger and larger number of molecules, assuming the properties characteristic of fluids and therefore not showing elastic reactions, undergo displacements beyond the positions at which they would have arrived had the links not been severed; so that a deformation in the original sense is possible after the elastic forces, through the reaction of the remaining parts, have reached their maximum. If this is the case, the conception introduced by Ewing into his study of magnetic hysteresis would, in the case of elasticity, be founded on actual occurrences. The author proceeds to investigate the time-relations between the distorting couple and the angle of torsion. He finds that Peddie's formula (Phil. Mag. 38. p. 36) for the damping of oscillations is not realised in practice, since the effect of elastic hysteresis is not taken into account. Experiments made on nickel wire show that, when this is allowed for, the relations between the distorting couple and the angle of torsion as deduced from statical experiments can be safely introduced into the corresponding dynamical investigation. E. E. F.

542. *Duration of Seismic Records.* **E. Oddone.** (Rend. Acc. Linc. 4. pp. 425–430, 1895.)—The author tabulates the earthquakes of the years 1893 and 1894, together with the duration of the disturbances as observed at Rocca di Papa, Roma, Siena, and the distances of these stations from the epicentres. The duration of the movements increases with the distance. Thus the disturbance caused by the weak shocks at Colli Laziali lasted 10 sec. in the Rocca di Papa Observatory close by, and 70 sec. at Roma, 25 km. distant. Owing to the greater distance, this shock was, however, not recorded at Siena, 220 km. distant, and the time-increase in the disturbances does not of course depend on the distance alone. The Argentine earthquake of October 27, 1894, disturbed the instruments, over 11,000 km. away for 1800, 2100, 3600 sec., the order being as stated above; the earthquake in Turkestan (5000 km.), Nov. 5, 1893, was noticeable for 420, 1260, — sec.; various severe shocks of 1893 at Zante were recorded at Roma only, 850 km. distant, for 160, 240, 240, 240, 540 sec. For the maximum phase the velocity of propagation seems to be constant, about 2·5 km./sec., but it does not correspond with the ordinary longitudinal propagation of the wave. For the initial phase, the velocity appears variable and often considerably larger, up to 7 km. The first indications of the magnetograph do not coincide with the beginning of the movement, and the peculiarities of the instruments and of the soil render the calculations very uncertain. H. B.

543. *Meudon Observatory for Astro-Physics.* **J. Janssen.** (C. R. 120. pp. 1237–1240, 1895.)—Owing chiefly to the want of funds, the cupola of the Meudon Observatory, whose erection was decided upon in 1876, has only now been completed. The mechanical and optical outfits were supplied by Gautier and by Henry a year ago. Financial considerations have also delayed the publication of the 'Annales' of this Observatory, which are otherwise ready, so that most communications from Meudon have appeared in the 'Comptes Rendus,' and have prevented the reproduction of many of the solar and stellar photographs, comprising the photometric observations of comets, and otherwise impaired the work carried on at Meudon. H. B.

544. *Palladium and Hydrogen.* **C. Hoitsema.** (Zschr. phys. Chem. 17. pp. 1–42, 1895.)—The paper contains an elaborate practical and theoretical study of the property which palladium possesses of absorbing hydrogen in quantities depending on the temperature and pressure; there are numerous tables and curves, for which the original paper must be inspected. Troost and Hautefeuille, as the result of their experiments, came to the conclusion that a compound Pd_2H is formed, in which the hydrogen dissolves to a greater or less extent. The author states that

an accurate consideration of their experiments shows that there is no ground for a belief in Pd_2H, and that their experimental results show great uncertainties at critical points.

Referring to the author's own work, each curve which represents the relation between p, the pressure, and c, the quantity of hydrogen in the palladium, for temperatures between 0° and 190°, consists of three parts—two steep portions connected by another nearly horizontal. The first part changes gradually into the second, and the latter similarly into the third; there is no discontinuity. The curves give the impression of a continuous absorption, which, however, is certainly different in character from other known phenomena. An explanation of the results can be given by assuming that the hydrogen condensed, so to speak, in the palladium undergoes certain critical phenomena at temperatures much higher than the critical point of liquid hydrogen.

The application of van't Hoff's laws for solid solutions leads to the conclusion that hydrogen under a low pressure dissolves as H, at a higher pressure as H_2. This, however, only holds for weak concentrations. The behaviour of the palladium depends to some extent on its condition, as to whether it is in the form of sheets or wire or in the spongy state. **A. Gs.**

545. *Crystal Form of Chemically Simple Substances.* **F. Rinne.** (Zschr. phys. Chem. 16. pp. 529–545, 1895.)—Retgers has shown that bodies with not more than two atoms in the molecule crystallise almost always in the cubic and hexagonal systems, but concludes that no further regularity is to be observed. Rinne finds that the majority of triatomic bodies are also cubic or hexagonal. He tabulates the axial ratio, the habit, and the more important angles of the chemically simple bodies that crystallise in the hexagonal or tetragonal systems, and finds that in each system there are a few types, the members conforming to each type showing a marked similarity in habit and angle. A large part of the paper is controversial, and deals with objections made by Retgers to a former paper by Rinne on the same subject.

J. W. C.

546. *Frequency of Recent Earthquakes.* **C. v. Zenger.** (C. R. 120. pp. 1377–1379, 1895.)—According to the author, earthquakes occur when swarms of shooting-stars and aerolites pass, and these passages coincide with (precede or follow immediately) the culmination of the centre of a solar perturbation in the central meridian of the disc; there is hence connection with the solar day of 12·6 of our days. The discharges of cosmic electricity disturb the atmosphere and the globe for days. Thus, between April 9 and 15, 1895, earthquakes accompanied by magnetic and solar disturbances were observed in Calabria, Carinthia, and over almost all Central Europe, near Okroglo etc. An analysis of the seismic statistics of Gérigne shows that for the years 1884 to 1888, the solar period,

April 12, the meteoric swarms, April 9 to 13, coincided with severe disturbances all over the globe. Zenger would class volcanic eruptions with these phenomena. H. B.

---

547. *Elastic Hysteresis.* **Cantone.** (Rend. Acc. Linc. 4. pp. 437–446, 1895.)—Previous work on the flexure of brass and on the internal friction of metals by this author has collected sufficient data for an investigation as to how the work consumed in a bilateral cycle of deformations varies with the forces applied. For this purpose the author computed the hysteresis-areas of deformation by torsion for a number of metals, including iron, nickel, aluminium, platinum, copper, and silver, and the areas for brass due to flexure and torsion. A formula was deduced from theoretical considerations, according to which these areas should be equal to the product of the extreme deforming moment and the permanent torsion multiplied by π. This formula is very approximately confirmed by results obtained with metals of appreciable plasticity, unless the deformations are very large. A deduction from this to the dynamical method of investigating elasticity is embodied in the following law:—The ratio between the decrement of the amplitude of the oscillating wire and the permanent deformation in the corresponding statical cycle is constant and equal to π. E. E. F.

---

548. *Seismic Observations at Grenoble.* **Kilian.** (C. R. 120. pp. 1436–1438, 1895.)—On April 14, at $10^h\ 29^m\ 20^s$ P.M., Paris time, the seismographic apparatus at Grenoble—an indicator, system Kilian-Paulin, and a seismograph, system Angot—marked a shock, and the chronometer was unclinched. Although the papers next morning reported the Laibach earthquake, the coincidence was questioned because some time before a steam-roller had not affected the instruments in the least, as they rest on isolated foundations in the basement. Fouqué suggested trying the steam-roller of 14,500 kg. once more. The instruments were not in the least influenced; the basement near the roller seemed very slightly affected; the higher stories quivered visibly. Rebeur-Paschwitz has pointed out that the Japan earthquake of March 22, 1894, that of Servia, April 8, 1893, and of Turkestan, Nov. 5, 1893, were also marked by the Grenoble instruments. The recent earthquake at Florence of May 18, 1895, registered itself by a vertical movement from below. Fouqué remarks that the intensity of the perturbations signifies less than their character. The steam-roller produces irregular shocks (which were particularly noticed when the roller moved at right angles to the walls of the building); the earthquake movements are undulatory and of an accumulative nature. H. B.

---

549. *Absence of Gases in the Water from the Bottom of the Lake Geneva.* **A. Delebecque** and **A. Le Royer.** (C. R. 120.

pp. 1438–1440, 1895.)—Of the bottles constructed to bring up water from great depths, those of Mill and of Buchanan are said to be unable to resist the great pressures, whilst those of the 'Travailleur' and the 'Vöringen' resist only because they are fitted with joints and valves. These valves must become leaky at greater depths, and if any gas were held in solution it would escape when, on lifting the bottle, the pressure decreases. It is, however, improbable that such water should contain gases. The authors quote an experiment in favour of this view. An iron vessel is surmounted by a brass frame supporting a glass burette of 200 c.c. in a ring; the glass can be tilted. The apparatus is sunk, the glass being full of mercury. At the required depth the glass is inverted bo means of a Rung device; two-thirds of the mercury flows into the iron vessel and seals the water which fills the bottle. Gas-bubbles would collect above the water, but could not escape. This apparatus was tested near Ouchy in depths of 250 and 290 m. (the maximum depth is 310 m.), where the pressure is 24 and 28 atm. Not a trace of gas was brought up. Kept for a day, first in the sunshine, then in a warm room, the 120 c.c. of water evolved less than 1 c.c. of gas, for which the authors account by the rise of temperature, from 5° to 20°. The general conclusion that the gas held in solution is independent of the pressure is not further supported. H. B.

550. *Moon Photographs.* **Lœwy** and **Puiseux.** (C. R. 121. pp. 6–12, 1895.)—Weinek is enlarging the Paris photographs on a scale corresponding to a Moon diameter of 4 m. In comparing his enlargements with the Moon maps of Schmidt of Athens, which still remain the most faithful, he finds 95 new craters and a number of doubtful additions. By examining different prints from one plate of March 14, 1894, the authors confirm 67 of these 95 craters. The paper discusses the possibilities of such examinations of prints of different intensities. They have often secured 15 and 20 exposures in less than 2 hours, and believe that the comparison of at least three plates and of prints obtained from them under different treatment will be very profitable. There is a useful subjective element in photographs, whilst drawings must be studied with reserve. Dawes and Foucault have proved that the optical power of a telescope can be expressed in seconds of arc by the quotient 137/A, in which A is the aperture in mm. Observers of double stars have aspired to pass this limit, but we easily see what we wish to see. This applies with still greater force to the Moon than to the stars. Owing to irradiation small shaded spots appear of reduced dimensions. With a good equatorial of 0·54 m. we ought to be able to distinguish 0″·25. As yet the authors have not been able to go beyond 0″·5; but their mechanism was not perfect, and this year, after overcoming this difficulty, they have never been able to secure that absolute calm, so rare in all climates, required for the 0·7 or 1·5 sec. of exposure. The study of the different graduations of light seems very fruitful. They point out various differences

between their photographs and Schmidt's Atlas, and finally refer to the parasitic hollows in certain walls, which, in their opinion, Suess explained correctly by assuming that the eruptive force found less difficulty in breaking through the projecting parts than through the depressed shell. H. B.

551. *Standard Barometer.* **K. R. Koch.** (Wied. Ann. 55. pp. 391–397, 1895.)—The so-called "standard" barometer possesses several defects, in consequence of which the readings of different instruments, under similar conditions of temperature and pressure, do not agree nearer than a few hundredths of a millimetre. The errors arising from imperfection of the vacuum, uncertainty as to the density of the mercury, capillarity, and scale fluctuations are sufficiently serious; but the author thinks the gravest fault is that due to the practice of assuming the temperature of the barometer-column to be the same as that of a thermometer placed outside it. To examine these sources of error, an experimental barometer has been constructed, arranged so that the vacuum can be checked and the tube refilled when necessary; also, mercury can be removed for the purpose of determining its density. Special attention is given to the purification of the mercury: dampness and grease are not the principal causes of density changes; these variations are due to traces of the heavier metals. By repeated washing, desiccation, and distilling, the mercury was obtained so pure that ether formed no deposit with it. Differences of density in the mercury of "standard" barometers may be as much as 0·002, which may cause an error of 0·1 mm. in the readings. A thermometer placed outside the barometer-tube may easily record a temperature different by half a degree from the true temperature of the column of mercury. It is further suggested that the temperature of the scale should also be measured by a thermometer inserted in a mercury cup within the metal. R. A.

552. *Instrument for Measuring the Distance and Height of a Remote Object.* **Schrader.** (C. R. 121. pp. 40–43, 1895.)—Considering the line joining the place of the observer and the distant object as the hypothenuse of a right-angled triangle, of which the two other sides represent respectively the difference of height and the horizontal distance between the observer and the object, the problem of finding the desired magnitudes is reduced to that of devising some apparatus by means of which a triangle proportional to the real triangle shall be produced: the proportion of the two triangles corresponding—if the observer is a map-maker—to the scale of the map desired. The author gives a concise description of his instrument, which it is impossible to condense to any large extent, for which reference must be made to the original paper. The error in estimating a given distance is between 1/2000 and 1/4000 of the actual length. A. Gs.

553. *Curve-Tracer for Tides.* **A. Faidiga.** (Zschr. Instrumk. 15. pp. 239–244, 1895.)—This instrument, which the author has named an "Inferentiator," is designed for predicting the tides, by drawing the resultant to the solar and lunar component curves. It is intended for use at the harbour of Trieste. The two curves, from which the resultant is to be drawn, are plotted out upon a plane with their axes parallel to one another, at a convenient distance apart. A pantograph, having tracing-points at the extremities of its two equal, longer arms, and a stylus at the junction of the two equal, shorter arms, the shorter arms being half the length of the longer arms and jointed to the middle points of them, is supported in such a way that the line joining the two tracing-points is at right angles to the axes of the two curves, and so that the pantograph can slide in a direction at right angles to this line. There is thus a tracing-point for each of the component curves, and a stylus bisecting the straight line between these two points, the three points being always in one and the same plane. If one of the tracing-points be supposed fixed, while the other is extended through a distance $2a$, the stylus will be moved through a distance a. Consequently, if the two tracing-points are made to follow their respective curves, the line joining these points being always at right angles to the axes, the stylus will trace a resultant curve with ordinates drawn to half the scale of the components. If, now, a second pantograph, precisely like the first, is supported in the same straight line with it, the stylus of the second pantograph being linked with the stylus of the first, it is clear that the tracing-points of the second pantograph will map out a curve having ordinates drawn to twice the scale of the curve traced by the stylus of the first; that is to say, the scale of ordinates of these final curves is the same as that of the original components. The mechanism which maintains the pantographs always in the same right line, and which enables the tracing-points to follow the curves as the pantographs move in the direction of the axes, is clearly illustrated by drawings which accompany the paper. The original description of the apparatus appeared in 'Bollettino della Società Adriatica di Scienze' of Trieste, vol. xvi. (1895). R. A.

---

554. *Relation of Atomic Weights of Hydrogen and Oxygen.* **E. W. Morley.** (Zschr. phys. Chem. 17. pp. 87–106, 1895.)—This paper is an abstract of the first part of a memoir on the atomic weight of oxygen now publishing by the Smithsonian Institution; it gives some account of a determination of this constant by determining the ratio of the densities of oxygen and hydrogen, and the ratio of the volumes in which they combine. The density of oxygen was determined by three series of forty-one experiments. In the first series three different globes were used; they were filled, at the temperature of the laboratory, with oxygen whose purity was elaborately determined. In the second series two

globes were used; they were filled with oxygen at the temperature of the laboratory, but neither temperature nor pressure were measured directly. A globe had been filled with hydrogen, of which the pressure was determined at 0° C. With the help of a delicate differential manometer, the temperature and pressure of the oxygen to be weighed were made equal to those of the hydrogen which was used for comparison. In the third series seven globes were used; they were filled, at the temperature of melting ice, with oxygen from different sources. The capacity of some of the globes used was more than twenty litres. The density of hydrogen was first determined in the same way, in two series, consisting of thirty-four experiments. But fearing the effect of contamination of the gas with the vapour of mercury (as was also suggested by Lord Rayleigh), the author devised a new method. A tube containing 600 grammes of palladium was charged with hydrogen. This tube had no stopcock, but a substitute requiring no lubrication and absolutely proof against all leakage. This was weighed: its hydrogen was transferred to an apparatus where its volume and pressure were measured at the temperature of melting ice, and the palladium was weighed again. Three series of experiments were made, with two different apparatus for the measurement of pressure; one of these contained no stopcocks, and was proof against all leakage. The values obtained for the densities of the two gases at standard temperature, and under standard pressure at the sea-level in latitude 45°, are given in the following table:—

	Density of Oxygen.
Series I.	1·42874 ± 0·000034
,, II.	1·42882 ± 0·000048
,, III.	1·42912 ± 0·000048

	Density of Hydrogen.
Series I.	0·089934 ± 0·0000067
,, II.	0·089967 ± 0·0000106
,, III.	0·089883 ± 0·0000049
,, IV.	0·089877 ± 0·0000088
,, V.	0·089863 ± 0·0000034

Considering the sources of error in the first and second series of experiments on the density of oxygen which are due to uncertainty in the coefficient of expansion of the gas, the author assigns double weight to the third value, and computes the final mean,

Weight of 1 litre of oxygen .... 1·42895 ± 0·000034.

The first and second values for the density of hydrogen are rejected, and the other three are combined with the weights indicated by the probable errors, giving

Weight of 1 litre of hydrogen .. 0·08987 ± 0·0000027.

Correcting these for an error in the certified length of a metre obtained from the Société Génevoise, the final values are:—

Weight of 1 litre of oxygen .... 1·42900 ± 0·000034
Weight of 1 litre of hydrogen .. 0·089873 ± 0·0000027
Their ratio is .... 15·9002 ± 0·00061.

The ratio of the volumes in which oxygen and hydrogen combine was determined by a process which in one respect resembles that used by Leduc in two experiments. The density of the mixture of oxygen and hydrogen produced by the electrolysis of a solution of sodium hydroxide was determined, the excess of hydrogen in the mixture was measured by eudiometric analysis, and in the computation of the composition of the mixture from its density the deviations of the gases from Boyle's law were taken into account. In the latter two particulars the process differs from that of Leduc. It also differs in the method used to determine the density of the mixture: a voltameter was weighed; it was then made to deliver the electrolytic mixture into the apparatus for measuring volume and pressure (employed in the case of hydrogen), and the voltameter was weighed again. After pressure, volume, and temperature had been sufficiently determined in the apparatus, which could leak only in case of fracture, part of the gas was transferred, for analysis, to a eudiometer which, in the larger number of experiments, would admit of the explosion of 800 cubic centimetres of the mixture at once, and without contact of mercury during the explosion. Ten experiments were made, in each of which 24 grammes of the electrolytic mixture were weighed; the value found for the volumetric composition of water is as follows:—

Ratio of volumes .... $2{\cdot}0027 \pm 0{\cdot}00014$.

Combining this with the ratio of the densities, we have for the atomic weight of oxygen

$$O = 15{\cdot}879 \pm 0{\cdot}00013.$$

Another part of the same memoir is mentioned, but without details, in which is described a series of experiments in which weighed quantities of water were produced from weighed amounts of hydrogen and of oxygen. An abstract of this part of the memoir publishing by the Smithsonian Institution appeared in the 'American Chemical Journal,' Vol. 17. No. 4 (1895). The paper in the 'Zeitschrift' gives the final results of this part of the work as follows:—

Atomic Weight of Oxygen by Syntheses of Weighed Amounts of Hydrogen and Oxygen.

From the ratio of the hydrogen to the oxygen,

$$O = 15{\cdot}8792 \pm 0{\cdot}00032.$$

From the ratio of the hydrogen to the water,

$$O = 15{\cdot}8786 \pm 0{\cdot}00066.$$

The paper gives a summary of all other published results on the ratios of the atomic weights and of the densities of oxygen and hydrogen.

AUTHOR.

LIGHT.

555. *Discovery of a Third Permanent Radiation of the Solar Atmosphere in Gas from Clèveite.* **H. Deslandres.** (C. R. 120. pp. 1331–1333, 1895.)—The gas obtained from the mineral clèveite has already been found to give two out of the four solar radiations which had not before been recognised in any terrestrial body. These radiations are permanent, and are of importance as indicating gaseous constituents of the solar atmosphere. The author has now found in the gas from clèveite a third of these radiations: it is in the extreme red, and its wave-length (carefully measured with a grating) is 706·55. There are really two new lines in the extreme red; the second is a weak line, and its wave-length is only given approximately as 728·5. The relative intensities of the terrestrial and solar lines in the following table agree fairly well:—

Gas from Clèveite.		Solar Chromosphere.	
	Wave-lengths.	Wave-lengths (Young).	Frequency in 100 observations.
New rays in extreme red	728·5		
	706·55	706·55	100
Rays previously observed	667·8	667·83	25
	587·60 D_3	587·60	100 D_3

The author has compared the spectrum of this gas with that of argon prepared from air. The two have at any rate one radiation common, viz. $\lambda = 706{\cdot}55$. Ramsay has announced a similar fact, but without giving any wave-lengths. The nearest line to this in Crookes' list of the argon lines is $\lambda = 705{\cdot}64$; but, considering the difficulty of an accurate measurement in the extreme red, it is probable that the two lines are identical. The coincidence suggests (as noted by Ramsay) the existence of a third element common to the two gases; and this is supported by the fact that the argon line 706·55 varies in intensity, whereas its other lines are constant. There only remains a single permanent radiation of the solar atmosphere which has not been recognised in a terrestrial substance. This is the coronal ray 531·16, which is seen in the higher regions of the solar atmosphere and is probably due to a gas lighter than hydrogen. D. E. J.

556. *Tests of "Instantaneous" Shutters.* **K. R. Koch.** (Zschr. Instrumk. 15. pp. 244–247, 1895.)—The time of exposure corresponding to different forms of the so-called "instantaneous" shutter is measured by a tuning-fork method. A beam of light from an electric lantern is directed through a small aperture to a mirror carried by one of the prongs of the fork, from which it is reflected into the lens of a photographic camera. When the tuning-fork is at rest, the image formed upon the sensitive plate is

a bright spot, which becomes a line when the fork is set in motion. The camera can be rotated about a vertical axis through any required angle; and during this angular motion the image becomes a sinuous line, representing the rate of the fork. The "shutter" is now put in the path of the light, and its interval of exposure is calculated directly from the photograph of the curve upon the developed plate. The author compares the "shutters" of eight different makers; his results show that, within wide limits, the exposure for small time-intervals is in all cases more or less arbitrary. R. A.

557. *Standard Lamp.* **Violle.** (Bull. Soc. Franc. Phys. No. 65, 1895.)—Acetylene burnt under somewhat high pressure in a burner in which it can receive an appropriate amount of air, and which gives a large thin flame, yields a perfectly constant brilliant flame of remarkable whiteness, and uniform over a considerable surface. An adjustable stop may be placed in front of the flame; and so may be obtained a source of light whose constancy, intensity, and whiteness, comparable with those of the absolute standard, form a trustworthy and convenient practical standard. R. A. L.

558. *Spectrum Analysis of Gases evolved from Various Minerals.* **N. Lockyer.** (C. R. 120. pp. 1103–1104, 1895.)—Eighteen minerals have been examined: among them uraninite, from which Ramsay has obtained a gas giving the yellow line ascribed by Lockyer in 1869 to the hypothetical element helium. The author gives the wave-lengths of the spectral lines (hitherto unknown to terrestrial chemistry) given by the gases evolved from the minerals; also a table of coincidences of these lines with (1) chromospheric lines, (2) lines photographed during the 1893 eclipse, and (3) lines of the white Orion stars. (See also 'Nature,' vol. 52. pp. 7–8, 55–57, 214.) D. E. J.

559. *Refractive Index of certain Crystals for the Ultra-Violet.* **G. A. Borel.** (C. R. 120. pp. 1404–1406, 1895.)—The refractive indices are tabulated for rock-salt, chlorate of soda, potash alum, ammonium alum (all simply refracting), and the three indices for magnesium sulphate. The rays measured were the chief Fraunhofer lines and the ultra-violet rays Cd 9 to Cd 26. The temperature-coefficient is given for magnesium sulphate. A spectrophotographic method was used. R. A. L.

560. *Absorption Spectrum of Oxygen.* **J. Janssen.** (C. R. 120. pp. 1306–1310, 1895.)—As regards the continuous bands in the absorption spectrum of oxygen, the absorptive power is proportional to the thickness of the layer of gas multiplied by the square of its density. A tube 60 m. long filled with oxygen shows the absorption-bands near the D line when the pressure reaches

about 6 atmospheres. The question whether these bands are produced by atmospheric oxygen was decided in the course of a visit to the Algerian Sahara, whose dry atmosphere eliminates errors due to water-vapour. By integrating the products of length and square of density for the various layers of the atmosphere traversed by the sun's rays at different altitudes, 172 m. was found to be the equivalent length at 1 atmosphere for vertical incidence, and 2160 m. for an altitude of 4°. This is the equivalent of the 60 m. tube at 6 atmospheres above referred to. Observation in the Sahara proved indeed that these bands, invisible at noon, appeared when the sun reached an altitude of 4°. This demonstrates conclusively the terrestrial origin of these bands, and the curious law of the square of the density is of great interest to molecular physics. E. E. F.

561. *Circularly Polarised Light.* **B. Brunhes.** (Bull. Soc. Franc. Phys. No. 65, 1895.)—The author has constructed a rectangular isosceles prism, the hypothenuse of which is a plate of quartz 2 mm. thick cut at 45° to the axis, and placed with its principal section coincident with the plane of incidence (*i. e.* at right angles to one of the lateral faces of the prism). The prism is hollow, and filled with a liquid of the same refractive index as quartz. Plane or circularly polarised light is allowed to fall normally on the face of the prism, and is reflected either totally or, when alcohol occupies the space behind the prism, partially, from the back face of the quartz plate. The effects produced are described: the chief being that no phase-difference occurs between the two circular rays produced by reflection of a plane (ordinary or extraordinary) ray. R. A. L.

562. *Centred Optical Systems.* **A. Broca.** (J. Phys. 4. pp. 254–260, 1895.)—When a centred system presents the fault known as astigmatism, the aberrant beam produced after refraction by the homocentric beam issuing from a point outside the axis does not present any well-defined singular point. No definition of the focal surface can be given independent of the position of the diaphragm. But every such system possesses on its axis certain real or imaginary points where the aberrations are of the fourth order with respect to the aperture used on the first surface. It is easily seen that these points form part of a surface in which Sturm's straight lines coalesce, and the point of intersection of this surface and the axis is always a simple point. Now this surface, being symmetrical with respect to the axis, must cut it at right angles. Hence for every point in a surface normal to the axis which is situated near the axis, the aberrations will be infinitely small, and we shall have a true focal surface. It remains to be found under what conditions this surface will be a plane. The author investigates these conditions mathematically for a series of surfaces of different curvatures separating media of different refrangibilities. For the particular case of a series of lenses of

the same refractive power, the condition is that the total refractive power of the system, when compressed to infinite thinness, should be *nil*. This result was verified experimentally by the construction of a photographic objective satisfying these requirements. E. E. F.

563. *New Pupillometer; Direct Action of Light on the Iris.* **C. Henry.** (C. R. 120. pp. 1371–1373, 1895.)—Brown-Séquard observed a contraction in the pupils of frogs and fishes when a candle was approached, which he ascribed to the action of the light on the muscular elements of the iris, as the nerves of the parts cut out were no longer irritable. Henry separates the light falling on the iris from that falling on the retina of a living man with the help of a pupillometer constructed by Pellin and based upon the assumption, which he explains, that for a very small hole at a distance of 12·8 mm. from the cornea every millimetre of the pupil diameter is measured by 1 cm. of the diameter of the luminous source. The apparatus consists of a combination of three tubes increasing in diameter: the narrowest, next to the eye, is closed by a diaphragm with a very small hole; the third by a dim glass disc 10 cm. in diameter, with white concentric rings. Those peripheral portions of the glass which are not perceived by the retina illuminate the iris. If opaque copper rings are placed over the white rings, and these screens are suddenly removed, the conditions will be unchanged for the retina but not for the iris, and the effect which the partial suppression of the light falling upon the iris will produce on the pupil can be observed. This suppression produces mostly a dilatation of from $\frac{1}{8}$ to $\frac{1}{7\cdot3}$ sq. mm. for every sq. mm. of iris no longer illuminated. The effect is more marked on dark-coloured iris. If one eye is treated in this manner, and the other watched with a Houdin pupillometer, the diameter of the latter pupil is dilated by from 0·2 to 0·5 mm., which shows that the action of the light on the iris is partly a reflex action of central origin. The effects of coloured screens are not uniform. The observations explain the intense photophobia characteristic of iritis, and would tend to show that in photometrical work we systematically make a slight mistake. The iris contracts when directed towards the stronger light; when two lights have been perfectly equalised, a rod of Vicia sativa, placed in the middle between them, does not appear vertical until we have displaced it a little, probably on account of this movement of the retina. H. B.

564. *Absorption of Circularly Polarised Light.* **A. Cotton** and **Cornu.** (Bull. Soc. Franc. Phys. No. 65, 1895.)—M. Cotton has discovered substances (*e.g.*, a solution of a double tartrate of chromium and potassium) which absorb unequally right- and left-handed circularly polarised light. This was first observed by means of a very sensitive arrangement for analysing elliptical light. A plate of quartz, consisting of two parts each cut parallel to the

axis, but placed with their axes at right angles, is examined with a spectroscope. In plane-polarised light, the fringes of Fizeau and Foucault are formed; but if the light is elliptic the two halves of the fringes are displaced opposite ways; or if plates are used giving only a few fringes—preferably only one, such as to show the "teinte sensible"—the spectroscope may be dispensed with, and the difference of colour will show a small ellipticity; even that produced by a phase-difference of one-thousandth of a wave-length, between two rectilinear vibrations. Now if equal right- and left-handed circular vibrations are passed through a substance that absorbs them unequally, and then compounded, the result will be elliptically polarised light: that can be done with the substance above mentioned; and, further, the measurements made indicate an anomalous rotatory dispersion of these absorbing substances, analogous to the anomalous dispersion attending ordinary absorption. The difference of absorption is well marked in the case of the double tartrate; so that it is only necessary to illuminate two adjacent portions of a field with right- and left-handed light, and view it through a solution of the salt, to see the difference of intensity (with sodium light) or colour (with white light). Further, if the apparatus be inverted, so that the light traverses first the liquid and then the double circular polariser, the same phenomenon is observed; thus showing the very important fact (as M. Cornu remarks) that the analysis of plane-polarised light into two circular beams is not a mere mathematical fiction, but actually takes place in substances possessing the rotatory power. R. A. L.

565. *Spectrum of Pure Carbon.* **H. Deslandres.** (C. R. 120. pp. 1259–1260, 1895.)—M. Moissan has remarked that the carbons used in the electric furnace seem to be freed from impurities by the intense currents used. Two of these carbons were investigated spectroscopically by the author, who finds that the ends show no trace of the spectra of the alkalies and alkaline earths, and only very faint traces of the calcium spectrum. The purest parts are the small excrescences on the negative pole formed by carbon carried across from the positive pole. The author gives the wave-lengths and intensities of the lines seen in the spectrum of these excrescences. J. W. C.

566. *Furrowed Interference Phenomena.* **H. Poincaré.** (C. R. 120. pp. 757–762, 1895.)—It is now about fifty years since Fizeau, from a classical experiment, sought to establish the permanence of luminous motion during a very great number of oscillations. If one causes interference between two rays of white light whose difference of path is several thousand wave-lengths, no interference-fringes are directly observable; if, however, the interfering beams are received in a spectroscope, we notice that the spectrum is furrowed with dark bands, which correspond to the simple radiations which are extinguished by the interference. The

author then challenges the elementary interpretation of the experiment usually given, and proceeds to examine the case mathematically, his analysis being based upon Fourier's Theorem. He, however, finally arrives at the following conclusion:—The experiments of Fizeau and Foucault thus show us that the luminous motion presents a certain kind of permanence. If, for example, the difference of path of two rays from a diffraction-grating equals 10,000 wave-lengths, and 1000 bars of the grating are used, this experiment shows that between the luminous motion during the period 0 to 1000 oscillations and that during the period 10,000 to 11,000 oscillations, there is no such difference as between the two sets of luminous motions which emanate from different sources. Thus the complete analysis leads to precisely the same conclusion as that divined in advance by Fizeau. E. H. B.

---

567. *Regularity of Luminous Motion.* **Gouy.** (C. R. 120. pp. 915–917, 1895.)—A criticism of the above paper by Poincaré. The present author points out a restriction under which alone, in his view, Poincaré's results hold good. E. H. B.

---

568. *Astigmatism.* **G. Foussereau.** (J. Phys. 4. pp. 260–262, 1895.)—This is a correction of a paper published in the same volume, p. 169, as far as it applied to infinitely thin lenses. The reasoning previously given for mirrors holds good. E. E. F.

---

569. *Spectrum of Helium.* **C. Runge** and **F. Paschen.** (Berl. Ber. 30. pp. 639–643, 1895.)—Crookes has shown that the brightest line in the spectrum of the gas from clèveite is a yellow line which very nearly coincides with the line D_3 (occurring in the solar chromosphere and in many stars), and has asserted that clèveite gas contains the hitherto hypothetical element helium. The dispersion used by Crookes was not large enough to make the coincidence certain; and by using larger dispersion it has been clearly shown that the yellow line is double, whereas the line D_3 has never been seen double. Nevertheless Crookes is probably correct in saying that D_3 is identical with the clèveite line, but that in the sun it is broadened out so much that even with a high dispersion it cannot be divided. In support of this the authors state that they have succeeded in the laboratory in producing a similar broadening of the clèveite line. Lockyer is of opinion that there are several elements present in the clèveite gas, and that we cannot say what lines belong to helium. The authors have investigated this question. They find that the clèveite lines are arranged on a systematic plan, and that the spectrum, like almost all line-spectra consisting of a moderate number of characteristic lines, can be split up into a number of "series" [the "series" here referred to are

such as have been described by Kayser and Runge in their researches on the spectra of the elements, Abhdl. der Berl. Akad. 1888–1893]. They conclude that a large number of the clèveite lines, and especially the brightest lines, belong in all probability to one and the same element. [The solar line D_3 has recently been observed as a doublet by Hale and Higgins.] D. E. J.

---

570. *Light Phenomena during Crystallisation.* **E. Bandrowski.** (Zschr. phys. Chem. 17. pp. 234–244, 1895.)—The author, continuing his experiments (see these Abstracts, p. 111, n. 230), has repeated Rose's with arsenious anhydride crystallising from hydrogen chloride solution. He finds that the light phenomena take place when any modification of the anhydride is dissolved and crystallised from acid solution, and that nothing is seen from alkaline and neutral solutions. He further notes that the phenomenon can be repeated with the same quantity of arsenious anhydride. In seeking an explanation of these facts, the author finds that the light-production varies with the ratio of $As_2O_3 : HCl$, no light being observed when the amount of hydrochloric chloride is less or above certain limits which depend on those of the dissociation

$$As_2O_1 + 6HCl \rightleftarrows 3OH_2 + 2AsCl_3.$$

Rose also found that potassium sulphate under certain conditions evolved light on crystallisation. He believed that fused or amorphous potassium sulphate was essential for the experiment, and obtained this condition by fusing with sodium sulphate. On repeating the experiment with a mixture of potassium and sodium sulphates, the author finds that light phenomena are observed only when the potassium sulphate contains sodium sulphate, and is due to the separation of a double salt. Light is only produced when the ratio of sodium to potassium sulphate is greater than 1 mol. : 1 mol. and less than 1 mol. : $2\frac{1}{2}$ mols.; so that the phenomenon takes place through the separation of $2K_2SO_4Na_2SO_4$ from the solution. The percentage of SO_4 in the separated crystals is always 58·7; and when by regulating the concentration of the solution the separation of this double salt is assured, the light phenomenon will always take place. S. R.

HEAT.

571. *Rise of Temperature in Working Muscle.* **A. Chauveau.** (C. R. 121. pp. 26–30, 1895.)—The author has made experiments by lifting and lowering a weight, and by walking up and down stairs, on the heat evolved by muscles performing similar movements (i) when doing work against gravity, (ii) when assisted by gravity. He finds that the rise of temperature of the muscle is about 25 per cent. greater in the former case. Discussion of the result is promised later. R. A. L.

---

572. *Specific Heat of Superfused Salts.* **L. Bruner.** (C. R. 121. pp. 60–61, 1895.)—The following numbers are obtained with sodium thiosulphate:—

Limits of Temperature. ° °	Specific Heat.
94—17	0·584
83—16	0·586
83—16	0·588
65—16	0·590
55—16	0·599
47—17	0·602
36—17	0·595*
2—13	0·563

* In the original the number given is 0·395 (probably a printer's error).

The specific heat of the fused salt has therefore a maximum about the temperature at which it melts (48°). T. E.

---

573. *Specific Heat of Hydrogen Peroxide.* **W. Spring.** (Zschr. anorg. Chem. 9. pp. 205–211, 1895.)—The specific heat of hydrogen peroxide cannot be determined by mixing it with water, as there is then a considerable evolution of heat. So the method of cooling is adopted, and this can only be used for solutions less than 80 per cent. in strength, as decomposition occurs with a stronger solution. The results are:—

Per cent.	Specific Heat of Solution.	Specific Heat of H_2O_2.
74·54	0·7845	0·6893
71·54	0·7615	0·6739
60·48	0·7806	0·6276
34·25	0·8802	0·6208
30·59	0·9512	0·8065

These numbers show that the solution with 71·54 per cent. has the lowest specific heat for the solution, whilst that which contains 34·25 per cent. has the smallest value for the specific heat of the

H_2O_2 in the solution. 0·6208 is therefore a maximum value for pure hydrogen peroxide. Assuming that one oxygen atom in the hydrogen peroxide has the same atomic heat as in solid oxides, then its specific heat would be 0·684—a number greater than the upper limit found above. S. S.

574. *Remarkable Alteration of Structure of Glass through Heating.* **E. Přiwoznik.** (Zschr. anorg. Chem. 9. pp. 289–290, 1895.)—Certain specimens of glass tubing made of soda-glass, examined by the author, on being placed in boiling water, or, better, in boiling concentrated sulphuric acid, show the formation of an immense number of cracks on the inside and outside of the tube, which extend for only a short distance into the interior of the mass of the glass. The author explains the formation of the cracks by the assumption that the inner and outer surfaces are in a state of great tension, owing to which the action of heat causes them to split up in the manner above described. A. Gs.

575. *Determination of Ratio of the Specific Heats of Air.* **G. Maneuvrier.** (C. R. 120. pp. 1398–1402, 1895.)—The adiabatic compression of a gas is produced by the sudden release of a spring which forces a piston forward—an operation requiring only from $\frac{1}{37}$ to $\frac{1}{12}$ second, and the resulting increase of pressure Δp_q is at once measured by a null method, the vessel containing the gas being immediately put into communication with a second vessel containing gas at a pressure that is previously adjusted, there being in the joining tube a liquid index which does not move if the adjustment is perfect. The corresponding variation of pressure Δp_t for the same diminution of volume at constant temperature is given by

$$\Delta p_t = p(v/V - \epsilon)/(1+\epsilon),$$

where V is the volume of the containing vessel, v that of the cylinder of the compression-pump, p the initial pressure of the gas, and $1+\epsilon$ Regnault's compressibility-ratio for the gas, ϵ varying with the circumstances. Then, since $\gamma = dp_q/dp_t$, the required ratio is approximately $\Delta p_q/\Delta p_t$ if Δp, which in the experiments did not exceed 1 cm. of mercury, is small. The method can obviously be easily used for all temperatures and pressures. Under normal circumstances the following values were obtained:—For air 1·3924, for hydrogen 1·384, for carbonic acid 1·298. R. E. B.

576. *Comparison of Thermometers.* **F. Grützmacher.** (Zschr. Instrumk. 15. pp. 250–262, 1895.)—This is an account of a long series of tests upon mercurial thermometers made of different kinds of glass; the results are given in the form of tables of temperatures. Altogether fifteen thermometers are compared, of which ten are Jena glass, and the remaining five of hard glass

from Stützerbach. Some varieties of glass made from the silicates of boron and barium are difficult to form into capillary-tubes of definite bore; but a particular specimen of zinc-borate glass, free from alkali, is mentioned, which has a very small coefficient of expansion and possesses the advantage of being easy to work; moreover it alters less with age than other varieties. For resisting chemical action, and for use with rapid changes of temperature, a special kind of hard soda-glass is recommended; tubes made from this glass will, however, require careful calibration, as the irregularities in the bore are likely to be large. The tables show the comparative readings between the thermometers and a standard mercurial thermometer of Jena glass. R. A.

SOUND.

577. *Sensitive Flames.* **E. Bouty.** (C. R. 120. pp. 1260–1262, 1895.)—A sensitive flame can be made to roar by increase of pressure of the gas, by placing a tube 1–2 cm. in diameter above the orifice, by blowing a very small quantity of air into the flame through a capillary tube coaxial with the burner, or by an acute sound. In whatever way it is excited its properties are the same. A rotating mirror shows a tranquil base surmounted by a plume of brilliant irregular bands. Any note above a certain pitch brings about the roaring, even if the flame is entirely surrounded by a tube 3 or 4 cm. in diameter, or if the upper part is cut off by wire gauze. Wire gauze placed in the excited flame gives no sound if below a definite point *a* in the base, but when it is between *a* and the foot of the plume a hissing sound is heard. A small flame placed very near the base of the roaring flame shows no agitation if below *a*. If periodic pulsations are produced by admitting the gas through a vibrating reed, the appearance of the flame is quite different from that of a roaring flame. The author thinks that the orifice is not the seat of the disturbance, but that in the region just above *a* the gas and air mix in an irregular manner, small portions of the mixture escaping immediate explosion, but that a note whose pitch is sufficiently near that of the explosive sound can bring about the explosion. J. W. C.

578. *Propagation of Sound in Cylindrical Tubes.* **J. Violle** and **T. Vautier.** (C. R. 121. pp. 51–53, 1895.)—The observations were made in a wide conduit between Argenteuil and Corneilles. The authors find that, of sounds produced by musical instruments, the range over which the sound can be heard is greatly dependent on the pitch. A note of frequency 32 can be heard to a distance of 23 kilometres, whilst one of 4600 is extinguished after travelling 1800 metres. Extinction is always preceded by change of quality of the sound, the higher notes losing their musical character entirely. The dull sound given by burning a mixture of magnesium and chlorate of potash returns after reflexion at the far end of the tube as a sharp explosion. Applying a relation established by M. Boussinesq between the extinction-coefficient and the retardation of a sound, it follows that acute sounds travel a little more quickly than grave sounds, though this could not be established directly by the ear. J. W. C.

ELECTRICITY.

579. *Dispersion of Electric Waves.* **L. Graetz** and **L. Fomm.** (Wied. Ann. 54. pp. 626-640, 1895.)—From the standpoint of Maxwell's theory it is not to be expected that the dielectric constant of a substance should be a strictly constant quantity, but rather a quantity whose value depends upon the wave-length of the electrical waves by whose means it is determined. The authors have endeavoured to ascertain whether such an interdependence of dielectric constant and wave-length may be experimentally confirmed. Suppose a dielectric ellipsoid to be freely suspended in a uniform field of electric oscillations, then it will in general be deflected from its equilibrium position. This fact, previously dealt with by Graetz and Fomm, was here utilised for the determination of the dielectric constants of several substances, with the following results :—

Wave-lengths of electric oscillations in unspecified arbitrary units.	Dielectric Constants for						
	Sulphur.	Paraffin.	Water.	Copper.	Lead Bromide.	Lead Iodide.	Beryl.
100	Mean value, 4·131	Mean value, 2·20	Mean value, 73·54	∞	41·792	113·2	8·15
122					42·938	not given.	6·60
130					43·692	147·7	6·83
180					48·643	172·8	8·62
Remarks	No dispersion observable.	No dispersion observable.	Slight trace of dispersion.		Abnormal dispersion.	Abnormal dispersion.	Abnormal dispersion analogous to the optical dispersion with Fuchsin.

E. H. B.

580. *Forces acting on Electrified Bodies in a Liquid Dielectric.* **Gouy.** (C. R. 121. pp. 53–55, 1895.)—In order to explain the fact that in any dielectric the attraction between electrified bodies is inversely proportional to the specific inductive capacity, the author divides the force into two parts. If the bodies were in a vacuum, the force on an element of one of them would be $2\pi\sigma^2 ds$ outwards. If now the field is filled with a liquid dielectric,

the distribution of electricity being unchanged, each element of the dielectric will be acted on with a force

$$\frac{1}{8\pi}\frac{K-1}{K}\frac{dF^2}{dl}dv$$

in the direction in which F^2 changes most rapidly. This is equivalent to a hydrostatic pressure

$$\frac{1}{8\pi}\frac{K-1}{K}F^2$$

at each point (omitting the constant term). Hence the total force on the element is

$$\left(2\pi\sigma^2-\frac{1}{8\pi}\frac{K-1}{K}F^2\right)ds;$$

and since $F=4\pi\sigma$, this is equal to $\frac{2\pi\sigma}{K}ds$—the usual expression.
J. W. C.

581. *Distribution of Induced Magnetism.* **Ascoli.** (N. Cim. 4. 1, pp. 279–280, 1895.)—This is a note drawing attention to the extent to which the non-homogeneous character of the cylinders experimented on affects the conclusions drawn by the author in a previous paper. (See Abstract 321.) W. W.

582. *Double Refraction of Electric Rays.* **A. Righi.** (N. Cim. 4. 1, pp. 261–262, 1895: *also* Wied. Ann. 55. pp. 389–390, 1895.)—K. Mack has described under date Nov. 1894 an experiment in which a plate of wood behaved to electric waves as does a plate of doubly-refracting crystal to rays of light. The present author points out that prior to the above date, viz., May 27, 1894, he had himself described an experiment of like import and others of analogous signification though not precisely the same one as Mack's. Righi had also obtained circular and elliptical polarisation, the latter with a block of wood of such thickness as to behave like a quarter-wave plate. E. H. B.

583. *Long Sparks at the Surface of Water.* **A. Righi.** (N. Cim. 4. 1, pp. 245–248, 1895.)—In a previous paper the author dealt with the sparks produced on the surface of water and described their characteristics; he also put forward a theory to account for the phenomena. The present memoir describes an experiment illustrative of this theory. An adjustable spark-gap and a glass tube full of water are arranged in series and the discharge made to pass through them. From the inside of the tube of water proceed ten copper wires which pass through tightly-stopped apertures spaced equidistantly along the tube, each wire proceeding to a brass ball. The balls are held by rods of ebonite, the distances between the balls being graduated from small to large along the row. Now when the main spark-gap is set with a very

small opening, nothing noteworthy is observed on discharging through the apparatus. If, however, the balls of the main spark-gap are placed far enough apart, then the main discharge is accompanied by sparks between one or more pairs of the ten balls connected by the wires to the tube full of water. These subsidiary discharges commence at the smallest spark-gap, then take that and the next larger gap, and so forth. In the author's hypothesis these balls are to be supposed diminished in size, their number being at the same time proportionately increased until they represent the molecules of water. Then the subsidiary sparks between the balls in the row are held to be analogous to the sparks which occur on the surface of water on the conditions previously described. E. H. B.

584. *Rectified Currents for Secondary Cells.* **Pollak.** (Zschr. Elektrochemie, No. 7. pp. 133–137, 1895.)—This is claimed to be the first practical attempt to "rectify" alternating currents for the charging of secondary cells, and for electrolytic purposes generally. The "rectifier" is driven by a synchronous motor, supplied with current from a small transformer in the primary (3000 volts) circuit; the axle of this motor carries a commutator with the usual rectifying arrangement of bars and rings. As the work to be done upon this apparatus is only that necessary to overcome friction at the brushes and bearings, the power consumed is very small. The current to be rectified is taken from the secondary (65 volts) circuit of a step-down transformer, the primary being in the 3000-volt supply circuit. The local circuit, which starts from the rectifier, is arranged very similarly to the arc-light circuit of a station using rectified currents. It contains a water-resistance, to be used at starting, and a switch for putting-in either glow-lamps or secondary cells. The difficulty of charging secondary cells by a pulsating current, arising from the reversal of current by the cells as the minima of the charging pulsations are passed, is met by an adjustment of the rectifier-brushes. The author gives little more than an outline of the method; he arranges the brushes so that the charging-circuit is completely broken except for the increments of time corresponding to those parts of the current-curve near the maximum values of the successive pulsations; in this position, sparking at the brushes nearly vanishes.

The rectified current is used in a factory, not only for charging cells, but for electrolytic purposes; for driving unidirectional-current motors; and for arc- and glow-lamps. The apparatus has been working, almost without interruption, for the past six months. There seems to be some question as to the efficiency of the rectifying system, the author estimates it at 96 per cent. R. A.

585. *Measurement of Electrical Capacity by a Method based on the Sensitiveness of the Skin.* **H. Bordier.** (C. R. 121. pp. 56–59, 1895.)—Near a primary circuit carrying an intermittent current is placed a secondary which can slide along a graduated

rod so as to vary the coefficient of mutual induction between the two. If a condenser is put in multiple arc with the secondary, the terminals of the coil brought into two beakers of water, and a finger placed in each beaker, then on gradually moving the secondary towards the primary a position is found where the sensation produced by the induced current can just be perceived. If this position is noted for a series of condensers of known capacity, and a curve drawn, it gives by interpolation the capacity of any other condenser. By this method the author found for two condensers giving ·912 and ·915 by the ballistic method the capacities ·915 and ·91 microfarad. The human body proved to have a capacity ·0025, which is about 58 times greater than that of a homogeneous conductor with the same surface. J. W. C.

---

586. *Hysteresis Meter.* **F. Holden.** (El. World, 25. pp. 687–689, 1895.)—The paper contains a description of a hysteresis meter designed by the author, and used by him at the works of the General Electric Company in Lynn, Mass. The losses in sheet-iron, punched in rings, are determined by measuring the torque produced on the iron when placed between the poles of a rotating electromagnet. The torque is measured by means of a pointer attached to a spring; the spring is calibrated so that the ergs spent on the rings per cycle are determined by multiplying the degrees distortion by a constant. The total flux between the poles of the electromagnet is measured by means of a search-coil connected to a sensitive voltmeter. The speed of the electromagnet is determined from the speed of an electric motor by which it is driven. Curves are plotted connecting the loss in ergs per cycle with the speed and the induction. The total loss per cycle is seen to have two components, one constant for a given induction, and the other varying as the speed of the magnets; the former is due to hysteresis, the latter to eddy currents. It is assumed that eddy current losses are proportional to the speed of the magnets in order to facilitate the calculation. A mean of many readings gives

$$\text{Loss due to Hysteresis} = \mathrm{KB}^{1\cdot5},$$

K being a constant, and B the induction-density. W. G. R.

---

587. *New Method for Testing the Magnetic Properties of Iron.* **W. S. Franklin.** (Phys. Rev. 2. pp. 466–470, 1895.)—A rod of sectional area q of the iron to be tested is bent into the form of a long narrow ∩, and suspended from the pan of the balance. The legs of the ∩ are surrounded by long stationary magnetising coils containing n turns per cm. and connected as the two coils in a horseshoe magnet. The balance is tared, a weight equal to F dynes placed in the pan, and the current slowly changed till the balance is in equilibrium. Then if C is the value of the current,

$$\mathrm{H} = 4\pi n\mathrm{C} \text{ and } \mathrm{B} = \frac{2\pi\mathrm{F}}{q\mathrm{H}} + \mathrm{H}.$$

The hysteresis loss is measured by suspending from one pan of the balance a long straight rod of the iron. A coil of wire of medium length containing n turns per cm. surrounds the rod, and can be moved up or down. It being required to find the energy loss per c.c. of iron during a cycle in which the magnetising field changes from $+H$ through $-H$ to $+H$. A measured current C is passed through the coil, which is then moved up and down the rod a number of times, the current being reversed each time the coil reaches the top or the bottom, until the changes in the rod have become cyclic. The rod is then weighed during the upward motion of the coil, and during the downward motion. Let F be the difference of these two weights in dynes; then

$$W = \frac{F}{q},$$

where W is the energy per c.c. lost in the iron in one cycle. Experiments have been made under the author's direction by these two methods, and have given satisfactory results. W. W.

588. *Refraction and Dispersion of Electric Waves.* **A. Garbasso** and **E. Aschkinass.** (N. Cim. 4. 1, pp. 186–190, 1895.) —Hertz, in his experiments and determinations, always implicitly assumed that the vibrations of his exciters were simply sinusoidal. Sarasin and De la Rive, on the other hand, from the phenomenon of multiple resonance observed by them, supposed the primary radiation to be not monochromatic. After the work of Sarasin and De la Rive, Garbasso described other facts which showed further an analogy between electric radiation and white light. The present authors then determined to study the question more completely. They first measured the indices of refraction of petroleum for electric waves of different periods, but always found the same value, not a trace of dispersion being observable. The subject was then regarded from the standpoint of the electromagnetic theory of dispersion. Helmholtz has shown that the action which the material molecules exert on the waves of light may be considered as a phenomenon of resonance. Now it is probable that the periods of vibration peculiar to the molecules of matter are of the order of those of the visible rays, or, it may be, of the ultra-red rays. It is thus impossible that resonance should obtain between the electric waves of Hertz and the molecules of a body, and consequently impossible for an ordinary prism to disperse electric waves.

The authors then made a prism consisting of resonators, and found that with it they could refract electric waves, and that the deviation depended upon the dimensions of the resonator with which the phenomenon was studied. They further conclude that they have the same right to consider the radiation of a Hertz-exciter composite as we have to attribute a composite character to white light. [*Cf.* the article by Bjerknes, Phys. Soc. Abstracts,

p. 135, March 1895, from which it appears that this last claim is fallacious.] E. H. B.

589. *Use of Tubes of File-Dust in the Study of Electrical Interference.* **E. Branly.** (J. Phys. 4. pp. 273–275, 1895.)—The author explains and recounts his work on these arrangements possessing variable states of conductivity brought about by high electric pressure. He objects to Prof. Lodge's name "adherer," and to the explanation of mechanical approach thereby implied, rather attributing the effect to a modification of the medium lying and surrounding the conducting particles. To this end he adduces how solid mixtures consisting of conducting particles immersed in a dielectric are effective. However, he shows that when the dielectric coating is thick, a greater electromotive force is required to produce the first charge to low resistance than is necessary to do so on subsequent occasions. Also when still thicker the charged state only lasts while the high E.M.F. is in application. F. T. T.

590. *Declination Measurements with Needles of Various Magnetic Moment.* **C. Lagrange.** (C. R. 120. pp. 1333–1335, 1895.)—The author has compared the values of the declination given by the nearly astatic needle system of a reflecting galvanometer with those given by a self-registering magnetograph. He finds that the galvanometer-needles, which have a very small magnetic moment compared with that of the magnetograph-needle, give a curve which is similar to that given by the latter. The amplitude of the movements, however, are 15 to 25 times as great as on the magnetograph. A similar set of observations have been made with a large feebly magnetised bar, the magnetic moment being about $\frac{1}{40}$ of that of the magnetograph-needle, and here also the amplitude of the movements of the more feebly magnetised needle are considerably the greater. No attempts seem to have been made to discover whether there was a correction to be applied to the *magnetograph* reading on account of torsion of the suspending fibre. W. W.

591. *Spherical Reflectors for Arc-Lights.* **A. Nodon.** (L'El. 9. pp. 369–370, 1895.)—The author being engaged in lighting a shop with arc-lamps uses glass spherical globes, one hemisphere being internally silvered to form a hemispherical reflector and externally coated with opaque varnish. The arc is placed at the centre of the globe. When working the arc is noticed periodically to go out quite suddenly, to quickly recover and burn again with its usual brilliancy. On examining the carbons pieces are found to have broken off and fallen to the bottom of the globe. The phenomenon is explained by saying that the rays from the arc are brought to a focus on the carbons and cause them to burn away at points other than their extremities. The difficulty is overcome by replacing the hemispherical reflector by a parabolic one. The author concludes that hemispherical reflectors are unsuitable for use with arc-lights. W. G. R.

592. *Absorption and Emission of Electric Waves by Resonance.* **M. Planck.** (Sitz. Akad. Wiss. Berlin, pp. 289–301, 1895.)—If an electromagnetic wave of definite period proceeding through free space fall upon a secondary conductor whose own period closely agrees with that of the primary wave, then electric vibrations are excited in that secondary by resonance, such vibrations being the more marked the closer the tuning of the secondary conductor to the exciting wave. By this means the secondary conductor becomes itself the source of secondary waves which interfere with the primary waves in the surrounding space, and give rise to phenomena different from those due to the primary waves alone. The amplitude of this secondary oscillation and its reaction upon the primary waves is mathematically treated in the present paper, and calculated for several typical cases. E. H. B.

593. *Effect of Temperature on the Magnetic Properties of Bodies.* **P. Curie.** (J. Phys. 4. pp. 197–212 & 263–272, 1895.)—The author obtains what he calls the specific intensity of magnetisation (L), *i. e.* the magnetic moment divided by the mass of a body, by measuring the force acting on the body when placed in a non-uniform magnetic field, the rate of variation of which is known. If H is the strength of the field at the point where the object is placed, most of the results obtained are given in terms of K, where $K=\frac{L}{H}$. The body under observation, if a solid in the form of a fine powder, is enclosed in a glass or porcelain bulb which is surrounded by a porcelain jacket heated by an electric current.

(1) *Diamagnetic Bodies.*—The value of K is constant for all strengths of field between 50 and 1350 C.G.S. units. Except in the case of antimony and bismuth, the magnetic properties alter very little with temperature. Fusion and allotropic change, except in bismuth, selenium, and phosphorus, produce little or no change. The sample of Sb employed had been prepared by electrolysis, and at ordinary temperatures the value of K was $0{\cdot}683\times10^{-6}$. After being heated to 540° and allowed to cool, the value of K at 18° had changed to $0{\cdot}936\times10^{-6}$. The value of K at 540° is $0{\cdot}468\times10^{-6}$. For bismuth at temperatures between 20° and 273°, the value of K is given by

$$10^6K_t=-1{\cdot}35(1-0{\cdot}00115(t-20)).$$

When Bi fuses, K changes suddenly from $-0{\cdot}957\times10^{-6}$ to $0{\cdot}038\times10^{-6}$, but further heating does not alter the value.

(2) *Feebly Para-magnetic Bodies.—Oxygen.* The value of K is independent of the pressure, and if T is the temperature on the absolute scale,

$$K_T=\frac{33700}{T}10^{-6}.$$

Assuming that the nitrogen in atmospheric air produces no magnetic effect, the value of K for air is given by

$$K_T = \frac{7830}{T} 10^{-6}.$$

The experiments on solutions of Fe_2SO_4 confirm Wiedemann and Plessner's observations, and show that K for a dissolved salt varies inversely as the absolute temperature.

Palladium. For temperatures between 20° and 1370° the value of K is given by

$$K_T = \frac{0{\cdot}00152}{T}.$$

(3) *Strongly Para-magnetic Bodies.—Soft Iron.* Observations have been made between 20° and 1300°, and for field-strengths of from 25 to 1350 C.G.S. units. At temperatures between 756° and 1375° the curves showing the relation between L and H are straight lines passing through the origin, and thus for temperatures above 756° the susceptibility of iron is constant. For a given field-strength I decreases between 750° and 1280°, the rate of decrease being at first very rapid. At a temperature of 1280° K suddenly increases in value by about 50 per cent., but decreases steadily with further increase of temperature. The author considers that his experiments tend to show that an allotropic modification of iron is formed at temperatures between 860° and 1280°. The temperatures at which the susceptibility of nickel and magnetite undergoes its great change are 340° and 535° respectively. Above these temperatures K for both these bodies decreases regularly as the temperature rises. In the case of magnetite, between 850° and 1360° the value of K is given by

$$K_T = \frac{0{\cdot}0280}{T}.$$

W. W.

---

594. *Dielectric Hysteresis.* **H. Eisler.** (Zschr. Elektrotechnik. 12. 1895.)—The cyclic process of charging a condenser by alternating currents is accompanied by dissipation of energy within the dielectric, similar to the loss which occurs during the cyclic magnetisation of iron; this action is generally attributed to "dielectric hysteresis." There has been some discussion as to whether the C^2R losses are not sufficient, of themselves, to account for all the heat generated; and the author brings forward some further experimental evidence with regard to the deductions to be drawn from the work of Steinmetz, Benischke, and others. We are to suppose that the particles of the dielectric, corresponding to the elementary magnets, do not, under all circumstances of charge, oppose the same mechanical resistance to an alteration of their relative positions, but that this resistance increases with the rate at which the cycle is performed: there is, in fact, a *time lag*; and the dissipation of energy is therefore to be considered as a conse-

quence of "viscous" rather than "static" hysteresis. The author determines experimentally the work done in a condenser when charged cyclically, and compares this with the losses which occur when a steady potential-difference is maintained at the terminals. The periodicity is then varied, and an attempt is made to establish the law according to which the energy dissipated in a given cycle depends upon its duration. If S is the work done per cycle, on account of hysteresis, throughout the whole condenser, and if k is a constant depending upon the material of the dielectric, C_n being the particular value of the capacity corresponding to a frequency n, when E is the "effective" potential-difference, the general expression for the energy dissipated by dielectric hysteresis is

$$S = kC_n f(n) E^2.$$

The precise form of the function $f(n)$ is not known; it can only be said that $C_n f(n)$ becomes a maximum for a certain value of n. This result is deduced from the following experimental evidence:—(1) If condensers of different capacities, but of the same dielectric, are submitted to equal "effective" alternating potentials, the work done upon them, per period, is proportional to their capacity. (2) If one and the same condenser is charged to different "effective" alternating potentials of equal periodicity, the work done upon it, per period, is proportional to the square of the voltage. (3) The work done upon one and the same condenser by the same "effective" alternating voltage, of different successive periodicities, depends upon the periodicity. It increases, up to a certain point, with increase of periodicity, and having attained a maximum, it again diminishes. R. A.

595. *Potentiometer.* **A. Raps.** (Zschr. Instrumk. 15. pp. 215–222, 1895.)—This is an elaborate form of the potentiometer, and is intended for the comparison of electromotive forces by the method of Poggendorff and Dubois-Reymond. The attempt is made to provide an apparatus which is independent of changes of temperature; and which is, as nearly as possible, direct-reading. The adjustable resistances are of the pattern of Thomson and Varley slides, and are wound with manganin wire: the author gives no data as to whether resistance-coils of this material have a time-variation; he assumes that they keep constant, and that the temperature-changes are sufficiently small to be neglected. A further simplification is attained by the use of cadmium cells in the primary circuit; these are without appreciable variation in E.M.F. with temperature. The range of measurement is large; two sets of leads are provided, for low and high voltages respectively. R. A

596. *Heat radiated by the Skin under the Influence of Continuous Currents.* **Lecercle.** (C. R. 120. pp. 1368–1371, 1895.)—A continuous current which does not contract the muscles, does not affect a thermometer placed on the skin. The author asserts that

a thermometer placed at a distance of 3 cm. from the skin is slightly affected. The thermometer, a spiral with a flat bulb, was placed in a glass bell of 60 c.c. cemented on the shaved hind quarters of a rabbit, covering an area of 54 sq. cm.; dry air was being sucked through the bell during the experiments. The current was taken from the 100-volt circuit of the town, and passed from two metallic electrodes of 25 sq. cm. each, covered with deerskin, placed at the root of the thighs, to a third electrode of 20 sq. cm. placed in the lumbar region. The two rabbits, weighing 2000 and 2500 gr., were eating during the tests. With currents of 10 milliamperes the temperature decreased by 0°·05, with currents up to 50 it increased by 0°·45. Previous experiments with battery-currents had always shown a decrease in the radiated heat. When the bell was removed, the cutaneous temperature remained constant, that of the rectum decreased by 0°·2 or 0°·1 for weaker currents, and increased by 0°·1 for currents of from 40 to 70 milliamperes. The same readings were obtained when the one electrode was placed on the femur-tibia joint, not with electrodes on the neck and the lumbar region. H. B.

597. *Demagnetisation in Steel Magnets.* **E. J. Houston** and **A. E. Kennelly.** (El. World, 25. pp. 582–583, 1895.)—From experiments which they have made the authors conclude that for a steel magnet to retain its magnetism unchanged, the demagnetising force within the steel should be to the demagnetising force on the descending branch of the hysteresis curve of the sample of steel employed corresponding to the required intensity of magnetisation in the ratio of 1 to 3. Thus suppose I to be the value of the intensity of magnetisation in the steel which will produce in the air-gap the required strength of field. Further, let the value of the demagnetising force on the descending branch of the hysteresis curve corresponding to I be H. Then the largest value for the demagnetising force which it is safe to have in the magnet when the intensity of magnetisation is I will be $\frac{1}{3}$ H. W. W.

CHEMICAL PHYSICS.

598. *Fluorescence of Argon when sparked with Benzene.* **Berthelot.** (C. R. 120. pp. 1386–1390, 1895.)—With a slow discharge of either high or low frequency, a feeble violet glow is first noticed which changes eventually to green. The spectroscope shows two yellow lines 579 and 577, a green line 546 and a green band λ 516·5. The photograph reveals nitrogen lines, but these gradually disappear as the sparking is continued. After 7 hours discharge, a brilliant emerald fluorescence, visible in daylight, is observed. Photographs at this stage show the following lines:—579, 577, 546, 436, 405, 354, 313, 312, 420, 416, 385, and 358. The band λ 516·5 is due to vapour of carbon bisulphide, and 313 and 312 to those of mercury vapour. Of the other lines none coincide with those of helium or of the aurora borealis. Certain of the lines, however, coincide with those of mercury vapour, and point to its presence in the gas, notwithstanding the fact that the phenomenon takes place at normal pressure. S. R.

599. *Volumes of Aqueous Salt Solutions between* 100° *and* 150°. **K. Zepernick** and **G. Tammann.** (Zschr. phys. Chem. 16. pp. 659–670, 1895.)—Measurements were made on the volumes of solutions of NaCl, KCl, HCl, H_2SO_4, NaOH, Na_2SO_4, Na_2CO_3, and $CaCl_2$, of concentration $\frac{1}{4}$ to 4 gm. equivalents per kilo of water, by the dilatometer method. Vapour of bromobenzene under variable pressure was used as a thermostat; corrections were applied to reduce the observations (made under the saturation pressure of the liquid) to 1 atmo, and to allow for liquid sticking to the upper portion of the dilatometer-tube (the chief source of uncertainty). It has been shown that solutions behave, with regard to expansion, like the solvent exposed to an extra pressure which is independent of the temperature; *i. e.*, their thermodynamic surfaces ($f(pv\theta)=0$) are those of the solvent moved parallel to themselves along the axis of pressure. Also it is known that the expansion of water from 0° to a point about 120°–130° is the same for all pressures: it follows that the expansion of solutions of varying concentration, between the same temperatures, must be equal. The experiments confirmed this deduction, except in the case of calcium chloride, which is not so completely dissociated a salt as the others. R. A. L.

600. *Classification of Chemical Elements.* **L. de Boisbaudran.** (C. R. 120. pp. 1097–1103, 1895.)—A preliminary communication on a classification of the elements, which also contains a note (intended for publication on April 22nd, but inadvertently omitted) stating that the author's classification indicates the possible existence of an element having an atomic weight of about 3·9. Ramsay has since determined the density of helium,

and found it to be 3·88. The values of the densities of helium and argon are numerically the same as the atomic weights at which the author has arrived theoretically for hypothetical elements which seem to correspond to them. D. E. J.

---

601. *Combination of Nitrogen with Carbon Bisulphide by Sparking.* **Berthelot.** (C. R. 120. pp. 1315-1316, 1895.)—On sparking nitrogen in presence of carbon bisulphide over mercury, an absorption of the gas slowly takes place. The product has not been analysed, but must have the composition

$$n\mathrm{CS}_2+\mathrm{N}-m\mathrm{S},$$

if the mercury plays no part in the condensation. As, however, mercury sulphocyanide is found in traces after the experiment, the following change may take place:—

$$2\mathrm{CS}_2+2\mathrm{N}+\mathrm{Hg}=\mathrm{Hg(CNS)}_2.$$

The silent discharge also causes a condensation to take place accompanied by a special fluorescent phenomenon to be further examined. S. R.

---

602. *Solubility of Solids in Water and Alcohol.* **G. Bodländer.** (Zschr. phys. Chem. 16. pp. 729-730, 1895.)—The author has previously shown (Zschr. phys. Chem. 7. pp. 308-322, 1891) that the solubility of a salt which is soluble in water and insoluble in alcohol in a mixture of alcohol and water is expressed by the formula

$$\frac{\mathrm{W}}{\sqrt[3]{\mathrm{S}}}=\text{const.},$$

where W and S are the quantity of water and dissolved salt in 100 cub. cms. of the solution. Hollemann and Antusch (Rev. des Travaux Chim. des Pays-Bas, 13. pp. 273-306, 1894) have confirmed the above formula. The author points out that the variations found in examining trinitrobenzene, benzamide, and alanine are due to the fact that these compounds are not absolutely insoluble in the second solvent. S. R.

---

603. *Solubility of Superfused Substances.* **L. Bruner.** (C. R. 121. pp. 59-60, 1895.)—According to van't Hoff's theory of the "point of transition," the solubility of a solid substance at a temperature below its melting-point should be smaller than that of the substance in the state of superfusion at the same temperature. The author shows that this is the case for solutions of sodium thiosulphate in aqueous alcohol. T. E.

WILLIAMS AND NORGATE,

14 HENRIETTA STREET, COVENT GARDEN, LONDON;
20 SOUTH FREDERICK STREET, EDINBURGH;
AND 7 BROAD STREET, OXFORD,

PUBLISHERS AND IMPORTERS OF

FOREIGN SCIENTIFIC BOOKS,

Receive regularly from the Continent supplies of all important Books on Scientific Subjects.

MOST RECENT IMPORTANT CONTINENTAL PUBLICATIONS.

Abhandlungen, wissenschaftliche, der kaiserl. Normal-Aichungs-Kommission. [Fortsetzung der Metronomischen Beiträge.] 1. Heft. Anschluss der Normale der deutschen Maase und Gewichte an die neue Prototype des Meter und des Kilogramm. Berlin, 1895. 4to. V, 201 pp. Mit 16 fig. 8*s.* net.

Brunhes (B.). Cours élémentaire d'électricité. Paris, 1895. 8vo. Avec 137 fig. 4*s.* 6*d.* net.

Demarçay (E.). Spectres électriques. Paris, 1895. 4to. Atlas de 10 pl. 20*s.* net.

Dumont (G.) et **Baignères** (G.). Étude sur le transport de l'énergie à grande distance par l'électricité. Paris, 1895. 8vo. VI, 114 pp. Avec 77 fig. 5*s.* net.

Fleming (J. A.). Electrical Laboratory Notes and Forms, elementary and advanced. London, 1895. 8vo. 250 pp. 12*s.* 6*d.* net.

Frick (Dr. J.). Physikalische Technik speciell Anleitung zur Ausführung physikalischer Demonstrationen und zur Herstellung von physikalischen Demonstrations-Apparaten mit möglichst einfachen Mitteln. 6. Umgearbeitete und vermehrte Auflage. Von Dr. Otto Lehmann. Vol. II. Gr. 8vo. XXVI. u. 1054 Seiten. Mit 1016 eingedruckten Holstichen und 3 Tafeln. 20*s.* net.

Hospitalier (E.). Recette de l'électricien. Colligées et mises en ordre par E. Hospitalier. Masson. 3*s.* 6*d.* net.

Jahn (H). Grundriss der Electrochemie. Vienna. 8*s.* 6*d.* net.

Kolbe (Bruno). Einführung in die Electricitätslehre. Band II. Dynamische Elektricität. Mit 75 in den Text gedruckten Holzschnitten. 187 Seiten. 8vo. 3*s.* net.

Laffargue (J.). Les Applications mécaniques de l'énergie électrique. In-12, avec 320 fig. Paris. 2*s.* 6*d.* net.
Forme le No. 3 de la 'Bibliothèque électrotechnique.'

Lehmann (Dr. Otto). Elektricität und Licht. Einführung in die messende Elektricitätslehre und Photometrie. 7*s.* net.

Lüpke (Robt.). Grundzüge der wissenschaftlichen Elektrochemie auf experimenteller Basis. Berlin, 1895. J. Springer. VIII, 150 pp. Mit 46 fig. 3*s.* net.

Oppenheimer (C.). Grundriss der organischen Chemie. Berlin, 1895. Boas & Hesse, Sep.-Cto. 8vo. VII, 130 pp. 2*s.* 6*d.* net.

Poincaré (H.). Cours de Physique mathématique. Théorie analytique de la propagation de la chaleur. Paris, 1895. 8vo. 316 pp. Avec fig. 8*s.* 6*d.* net.

Schwerebestimmungen Relative durch Pendelbeobachtungen. Ausgeführt durch die k. und k. Kriegs-Marine in den Jahren 1892–94. Herausgegeben vom k. und k. Reichs-Kriegsministerium (Marine-Section). Umfang: 39½ Bogen Lex.-8vo. (522 Seiten Tabellen und 5 Tafeln). Geh. 18*s.* 6*d.* net.

Vogel (Dr. Fr.). Theorie electrolytischer Vorgänge. Halle. 5*s.* net.

Weierstrass (K.). Mathematische Werke. Herausgegeben unter Mitwirkung einer von der königl. preussischen Akademie der Wissenschaften eingesetzten Commission. II. Bd. Abhandlungen II. Berlin, 1895. Mayer & Müller. 4to. VI, 362 pp. 21*s.* net.

Zickler (Prof. Karl). Das Universal-Elektrodynamometer. Mit 8 in den Text gedruckten Figuren. 32 Seiten. 8vo. 1*s.* net.

CATALOGUES AND MONTHLY LISTS OF FOREIGN BOOKS ON APPLICATION.

PERIODICALS SUPPLIED WITH THE UTMOST REGULARITY AND AT VERY MODERATE TERMS.

WILLIAMS AND NORGATE,
14 HENRIETTA STREET, COVENT GARDEN, LONDON;
20 SOUTH FREDERICK STREET, EDINBURGH;
AND 7 BROAD STREET, OXFORD.

CAMBRIDGE UNIVERSITY PRESS.

The Scientific Papers of the late Prof. J. Clerk Maxwell. Edited by W. D. NIVEN, M.A., formerly Fellow of Trinity College. In 2 vols. Royal 4to. £3 3*s.* net.

Mathematical and Physical Papers. By Lord KELVIN (Sir W. THOMSON), LL.D., D.C.L., F.R.S., Professor of Natural Philosophy in the University of Glasgow. Collected from different Scientific Periodicals from May 1841 to the present time. Demy 8vo. Vol. I., 18*s.* Vol. II., 15*s.* Vol. III., 18*s.*

Mathematical and Physical Papers. By Sir G. G. STOKES, Sc.D., LL.D., F.R.S., Lucasian Professor of Mathematics in the University of Cambridge. Reprinted from the Original Journals and Transactions, with Additional Notes by the Author. Demy 8vo. Vol. I., 15*s.* Vol. II., 15*s.* [*Vol. III. in the Press.*

A Treatise on Analytical Statics. By E. J. ROUTH, Sc.D., F.R.S., Fellow of the University of London, Honorary Fellow of Peterhouse, Cambridge. Demy 8vo. Vol. I., 14*s.* Vol. II., 10*s.*

A Treatise on the Mathematical Theory of Elasticity. By A. E. H. LOVE, M.A., Fellow of St. John's College, Cambridge. 2 Vols. Demy 8vo. Vol. I., 12*s.* Vol. II., 12*s.*

History of the Theory of Elasticity, and of the Strength of Materials, from GALILEI to the PRESENT TIME. By the late I. TODHUNTER, Sc.D., F.R.S. Edited and Completed by Prof. KARL PEARSON, M.A.

Vol. I. GALILEI to SAINT-VENANT, 1639–1850. Demy 8vo. 25*s.*
Vol. II. SAINT-VENANT to LORD KELVIN (Sir William Thomson). Demy 8vo, in 2 Parts. 30*s.*

Hydrodynamics. By HORACE LAMB, M.A., F.R.S., formerly Fellow of Trinity College, Cambridge, Professor of Mathematics in the Owens College, Manchester. Demy 8vo. 20*s.* net.

Extract from Preface.—"This book may be regarded as a second edition of a *Treatise on the Mathematical Theory of the Motion of Fluids*, published in 1879; but the additions and alterations are so extensive that it has been thought proper to make a change in the title."

Electricity and Magnetism. By J. J. THOMSON, M.A., Cavendish Professor of Experimental Physics in the University of Cambridge. Crown 8vo. [*In the Press.*

The Steam-Engine and other Heat Engines. By J. A. EWING, M.A., F.R.S., M.Inst.C.E., Professor of Mechanism and Applied Mechanics in the University of Cambridge. Demy 8vo, with Illustrations, 15*s.*

Engineering Record, New York.—"Prof. Ewing's treatise furnishes a valuable addition to the literature of heat engines. . . . The matter is presented in well selected and attractive language, and what would otherwise be dry reading is made unusually interesting . . . . On the whole, Prof. Ewing has brought out a treatise which is admirable, so far as its scope extends. Its applications are mainly on the lines of English practice, and naturally so; but its exposition of the principles of steam-working are sound, and they will prove of undoubted assistance to every engineering student, whether American or English."

A Treatise on Elementary Dynamics. By S. L. LONEY, M.A., Fellow of Sidney Sussex College. Second Edition, enlarged. Crown 8vo, 7*s.* 6*d.* Solutions to the Examples, 7*s.* 6*d.*

"This is one of the best and most complete treatises on elementary dynamics which have come before us for a long time. The principles of the subject are stated with great clearness, and the illustrative examples are very appropriate."—*Athenæum.*

A Treatise on Elementary Hydrostatics. By J. GREAVES, M.A., Fellow and Lecturer of Christ's College, Cambridge. Crown 8vo. 5*s.*

"A brief examination of this treatise is sufficient to allow us to form a favourable opinion of its contents. Nearly every proposition or description shows that the author is a thorough master of his subject, and, what is also of equal importance, can impart his knowledge to his readers in language both concise and fresh."—*Nature.*

CAMBRIDGE NATURAL SCIENCE MANUALS.

PHYSICAL SERIES.

General Editor—R. T. GLAZEBROOK, M.A., F.R.S., Fellow of Trinity College, Cambridge, Assistant Director of the Cavendish Laboratory.

Mechanics and Hydrostatics. An Elementary Text-book, Theoretical and Practical, for Colleges and Schools. By R. T. GLAZEBROOK, M.A., F.R.S. Crown 8vo.
Part I. DYNAMICS. 4*s.* Part II. STATICS. 3*s.* Part III. HYDROSTATICS (nearly ready).

Educational Review.—"In detail it is thoroughly sound and scientific. The work is the work of a teacher and a thinker, who has avoided no difficulty that the student ought to face, and has, at the same time, given him all the assistance that he has a right to expect. We hope, in the interests both of experimental and mathematical science, that the scheme of teaching therein described will be widely followed."

Heat and Light. By R. T. GLAZEBROOK, M.A., F.R.S. Crown 8vo. 5*s.* And separately, HEAT, 3*s.*; LIGHT, 3*s.*

Nature.—"Teachers who require a book suitable for the class-room and the laboratory would do well to adopt Mr. Glazebrook's work."

London: C. J. CLAY & SONS,
Cambridge University Press Warehouse, Ave Maria Lane.

CLARENDON PRESS LIST.

By Prof. W. W. Skeat, Litt.D.

In Six Vols. Demy 8vo, with Portrait and Facsimiles. £4 16*s.*

THE COMPLETE WORKS OF GEOFFREY CHAUCER. Edited from numerous MSS.

In Two Vols. Demy 8vo, uniform with the above. £1 11*s.* 6*d.*

PIERS THE PLOWMAN. Edited from numerous Manuscripts, with Preface, Notes, and Glossary.

In One Vol. Crown 8vo, Cloth. 7*s.* 6*d.*

THE STUDENT'S CHAUCER. Being a Complete Edition of his Works. Edited from numerous Manuscripts, with Introduction and Glossary.

"If the Library Edition of Prof. Skeat's 'Chaucer' is one which no gentleman's library should be without, the Student's Edition is one which every lover of literature should acquire."—*National Observer.*

THE OXFORD ENGLISH DICTIONARY.

New Parts recently published. 4to. Paper Covers.

A NEW ENGLISH DICTIONARY on HISTORICAL PRINCIPLES. Founded mainly on the Materials collected by the Philological Society.

D—Deceit. Edited by Dr. MURRAY. 3*s.* 6*d.*
Deceit-eject. Edited by Dr. MURRAY. 2*s.* 6*d.*
F—Fang. Edited by HENRY BRADLEY, M.A. 2*s.* 6*d.*
Fanged-Fee. Edited by HENRY BRADLEY, M.A. 2*s.* 6*d.*

☞ The Delegates of the Press have arranged for the punctual issue of the letters D and F in Quarterly Sections. One Section at least, consisting of 64 pages, will be published quarterly at Half-a-crown.

6 vols. Medium 8vo, half-bound. £3 3*s.*

BOSWELL'S LIFE OF JOHNSON. With the Journal of a Tour to the Hebrides. Edited by G. BIRKBECK HILL, D.C.L., Pembroke College.

2 vols. Medium 8vo, half-roan. 28*s.*

LETTERS OF SAMUEL JOHNSON, LL.D. Collected and edited by G. BIRKBECK HILL, D.C.L.

FULL CLARENDON PRESS CATALOGUES POST FREE ON APPLICATION.

London:
HENRY FROWDE, Clarendon Press Warehouse, Amen Corner, E.C.

OPTICAL AND SCIENTIFIC INSTRUMENTS.

Spectrometers, Spectroscopes, Goniometers, Cathetometers, Optical Benches, &c., &c. Instruments for special purposes constructed to Clients' own designs. *Prices moderate. Price List free.*

W. WILSON (formerly Foreman at Messrs. Elliott Bros.),
56 CROGSLAND ROAD, CHALK FARM, N.W.

PUBLICATIONS OF THE PHYSICAL SOCIETY.

THE SCIENTIFIC PAPERS

OF THE LATE

SIR CHARLES WHEATSTONE, F.R.S.

Demy 8vo, cloth. Price 15*s.*; *to Members of the Society*, 7*s.* 6*d.*

Uniform with the above.

THE SCIENTIFIC PAPERS

OF

JAMES PRESCOTT JOULE, D.C.L., F.R.S.

Vol. I. 4 Plates and Portrait, price £1; to Members of the Society, 10*s.*

Vol. II. 3 Plates, price 12*s.*; to Members of the Society, 6*s.*

PHYSICAL MEMOIRS.

Part I.—Von Helmholtz, On the Chemical Relations of Electrical Currents. Pp. 110. *Price* 4*s.*; *to Members of the Society*, 3*s.*

Part II.—Hittorf, On the Conduction of Electricity in Gases; Puluj, On Radiant Electrode Matter. Pp. 222. *Price* 7*s.* 6*d.*; *to Members*, 5*s.* 8*d.*

Part III.—Van der Waals, On the Continuity of the Liquid and Gaseous States of Matter. Pp. 164. *Price* 6*s.*; *to Members*, 4*s.* 6*d.*

PROCEEDINGS.

To Members of the Society only, at the following prices:—

Vols. I.–IV. 2 vols., cloth, 25*s.*, unbound 23*s.*

Vols. V. & VI. 1 vol., cloth, 13*s.*, unbound 11*s.*

Vols. VII. & VIII. 1 vol., cloth, 13*s.*, unbound 11*s.*

Vols. IX. & X. 1 vol., cloth, 16*s.*, unbound 14*s.*

Vols. XI. & XII. 1 vol., cloth, 16*s.*, unbound 14*s.*

These prices do not include carriage.

Applications for these Vols. must be sent direct to

Taylor and Francis, Red Lion Court, Fleet Street, E.C.

INDEX TO ABSTRACTS.

GENERAL PHYSICS.

Page
541. Methods of Investigating Elasticity. *Cantone* 331
542. Duration of Seismic Records. *E. Oddone* 332
543. Meudon Observatory for Astro-Physics. *J. Janssen* 332
544. Palladium and Hydrogen. *C. Hoitsema* 332
545. Crystal Form of Chemically Simple Substances. *F. Rinne* 333
546. Frequency of Recent Earthquakes. *C. v. Zenger* 333
547. Elastic Hysteresis. *Cantone* 334
548. Seismic Observations at Grenoble. *Kilian* 334
549. Absence of Gases in the Water from the Bottom of the Lake of Geneva. *A. Delebecque & A. Le Royer* 334
550. Moon Photographs. *Lœwy & Puiseux* 335
551. Standard Barometer. *K. R. Koch* 336
552. Instrument for Measuring the Distance and Height of a Remote Object. *Schrader* 336
553. Curve-Tracer for Tides. *A. Faidiga* 337
554. Relation of Atomic Weights of Hydrogen and Oxygen. *E. W. Morley* 337

LIGHT.

555. Discovery of a Third Permanent Radiation of the Solar Atmosphere in Gas from Clèveite. *H. Deslandres* 340
556. Tests of "Instantaneous" Shutters. *K. R. Koch* 340
557. Standard Lamp. *Violle* 341
558. Spectrum Analysis of Gases evolved from Various Minerals. *N. Lockyer* 341
559. Refractive Index of certain Crystals for the Ultra-Violet. *G. A. Borel* 341
560. Absorption Spectrum of Oxygen. *J. Janssen* 341
561. Circularly Polarised Light. *B. Brunhes* 342
562. Centred Optical Systems. *A. Broca* 342
563. New Pupillometer; Direct Action of Light on the Iris. *C. Henry* ... 343
564. Absorption of Circularly Polarised Light. *A. Cotton & Cornu* 343
565. Spectrum of Pure Carbon. *H. Deslandres* 344
566. Furrowed Interference Phenomena. *H. Poincaré* 344
567. Regularity of Luminous Motion. *Gouy* 345
568. Astigmatism. *G. Foussereau* 345
569. Spectrum of Helium. *C. Runge & F. Paschen* 345
570. Light Phenomena during Crystallisation. *C. Bandrowski* 346

HEAT.

571. Rise of Temperature in Working Muscle. *A. Chauveau* 347
572. Specific Heat of Superfused Salts. *L. Bruner* 347
573. Specific Heat of Hydrogen Peroxide. *W. Spring* 347

[*Continued over-leaf.*

INDEX (*continued*).

HEAT (*continued*).

Page
574. Remarkable Alteration of Structure of Glass through Heating. *E. Priwoznik* 348
575. Determination of Ratio of the Specific Heats of Air. *G. Maneuvrier* 348
576. Comparison of Thermometers. *F. Grützmacher* 348

SOUND.

577. Sensitive Flames. *E. Bouty* 350
578. Propagation of Sound in Cylindrical Tubes. *J. Violle & T. Vautier* . 350

ELECTRICITY.

579. Dispersion of Electric Waves. *L. Graetz & L. Fomm* 351
580. Forces acting on Electrified Bodies in a Liquid Dielectric. *Gouy* ... 351
581. Distribution of Induced Magnetism. *Ascoli* 352
582. Double Refraction of Electric Rays. *A. Righi* 352
583. Long Sparks at the Surface of Water. *A. Righi* 352
584. Rectified Currents for Secondary Cells. *Pollak* 353
585. Measurement of Electrical Capacity by a Method based on the Sensitiveness of the Skin. *H. Bordier* 353
586. Hysteresis Meter. *F. Holden* 354
587. New Method for Testing the Magnetic Properties of Iron. *W. S. Franklin* 354
588. Refraction and Dispersion of Electric Waves. *A. Garbasso & E. Aschkinass* 355
589. Use of Tubes of File-Dust in the Study of Electrical Interference. *E. Branly* 356
590. Declination Measurements with Needles of Various Magnetic Moment. *C. Lagrange* 356
591. Spherical Reflectors for Arc-Lights. *A. Nodon* 356
592. Absorption and Emission of Electric Waves by Resonance. *M. Planck* 357
593. Effect of Temperature on the Magnetic Properties of Bodies. *P. Curie* 357
594. Dielectric Hysteresis. *H. Eisler* 358
595. Potentiometer. *A. Raps* 359
596. Heat Radiated by the Skin under the Influence of Continuous Currents. *Lecercle* 359
597. Demagnetisation in Steel Magnets. *E. J. Houston & A. E. Kennelly*. 360

CHEMICAL PHYSICS.

598. Fluorescence of Argon when sparked with Benzene. *Berthelot* 361
599. Volumes of Aqueous Salt Solutions between 100° and 150°. *K. Zepernick & G. Tammann* 361
600. Classification of Chemical Elements. *L. de Boisbaudran* 361
601. Combination of Nitrogen with Carbon Bisulphide by Sparking. *Berthelot* 362
602. Solubility of Solids in Water and Alcohol. *G. Bodländer* 362
603. Solubility of Superfused Substances. *L. Bruner* 362